US006047230A

United States Patent [19]

Spencer et al.

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[45] Date of Patent: Apr. 4, 2000

[54] **AUTOMATIC BICYCLE TRANSMISSION**

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[21] Appl. No.: **08/807,354**

[22] Filed: **Feb. 27, 1997**

[51] **Int. Cl.**[7] **F16H 9/00**

[52] **U.S. Cl.** **701/57**; 701/51; 701/59; 474/70; 474/78

[58] **Field of Search** 701/51, 55, 56, 701/57, 59; 474/70, 80, 81, 110

[56] **References Cited**

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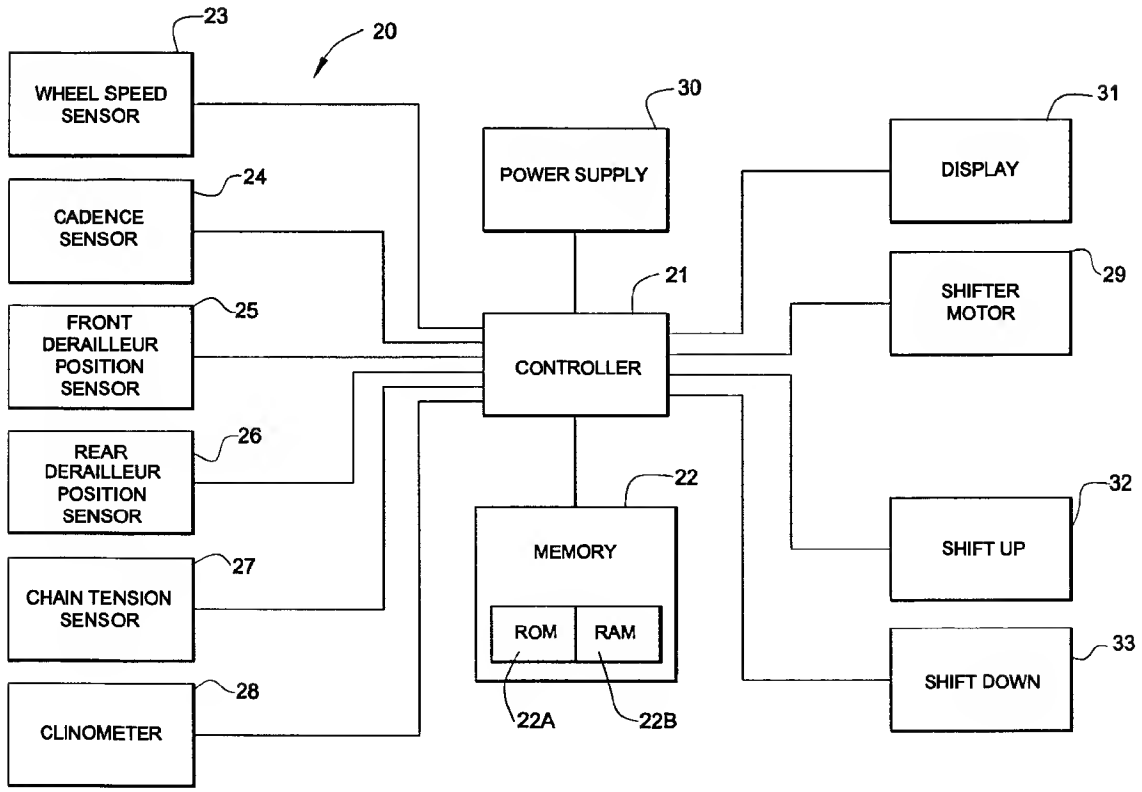
Primary Examiner—Tan Nguyen

Attorney, Agent, or Firm—Banner & Witcoff, Ltd.

[57] **ABSTRACT**

A gear shifting system for a human-powered chain- or belt-driven vehicle includes a wheel speed sensor, a cadence sensor, a gear changer position sensor, a tension sensor, a clinometer, a controller and a gear changer actuator. The wheel speed sensor senses a speed of a wheel, while the cadence sensor senses a drive rate that a torque drive member drives a torque-transmitting member. The gear changer position sensor senses a position of a gear changer that positions the torque-transmitting member with respect to a plurality of gears. The tension sensor senses a tension of the torque-transmitting member that is transmitting a torque applied to the torque-transmitting drive member to a gear. The clinometer senses an inclination of the vehicle. The controller generates a control signal based on the sensed wheel speed, the sensed torque-member drive rate, the sensed torque-transmitting member tension, the sensed vehicle inclination and the sensed gear changer position. The gear changer actuator is coupled to the gear changer and moves the gear changer in response to the control signal by positioning the torque-transmitting member with respect to the plurality of gears.

27 Claims, 24 Drawing Sheets



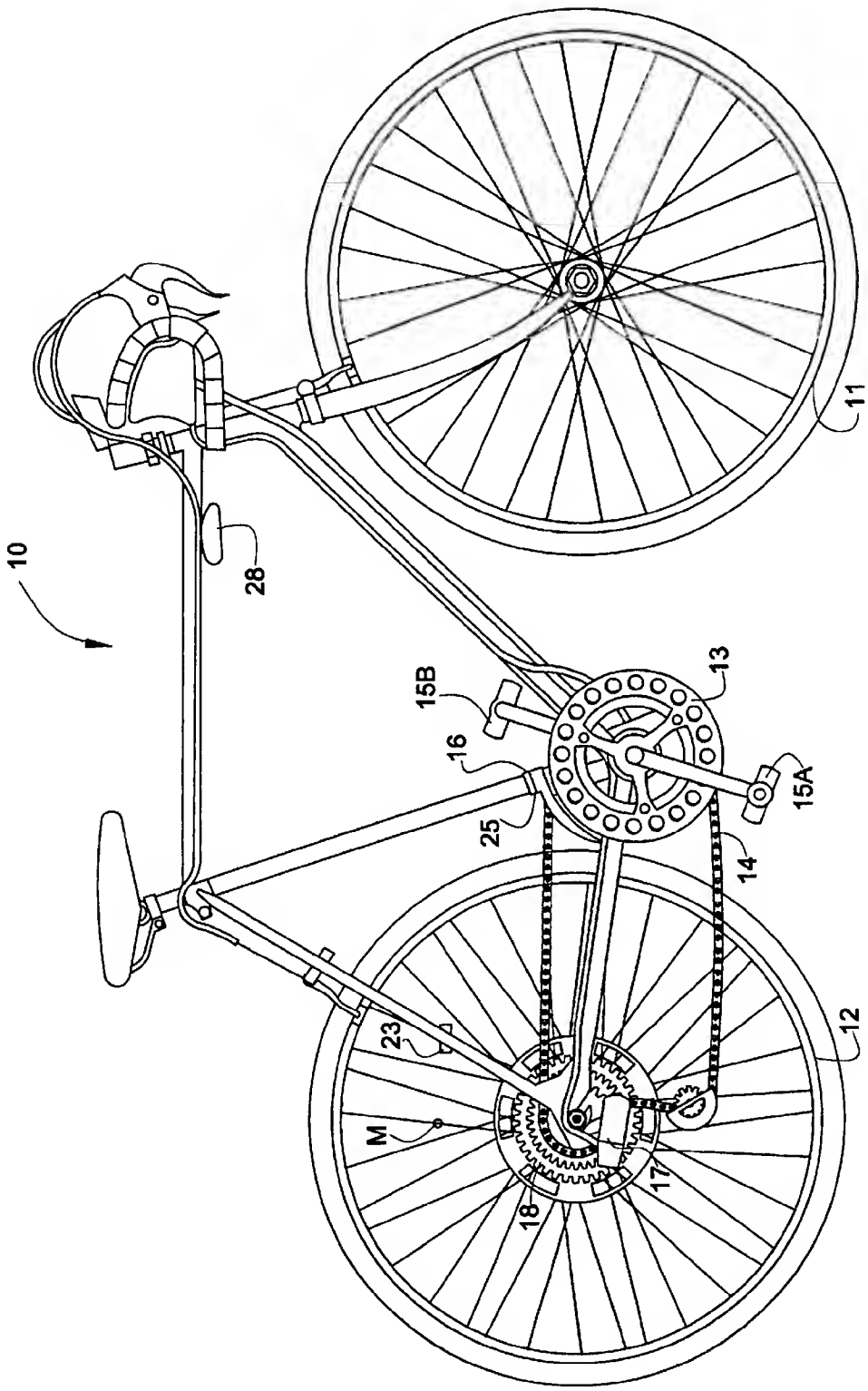


FIG. 1

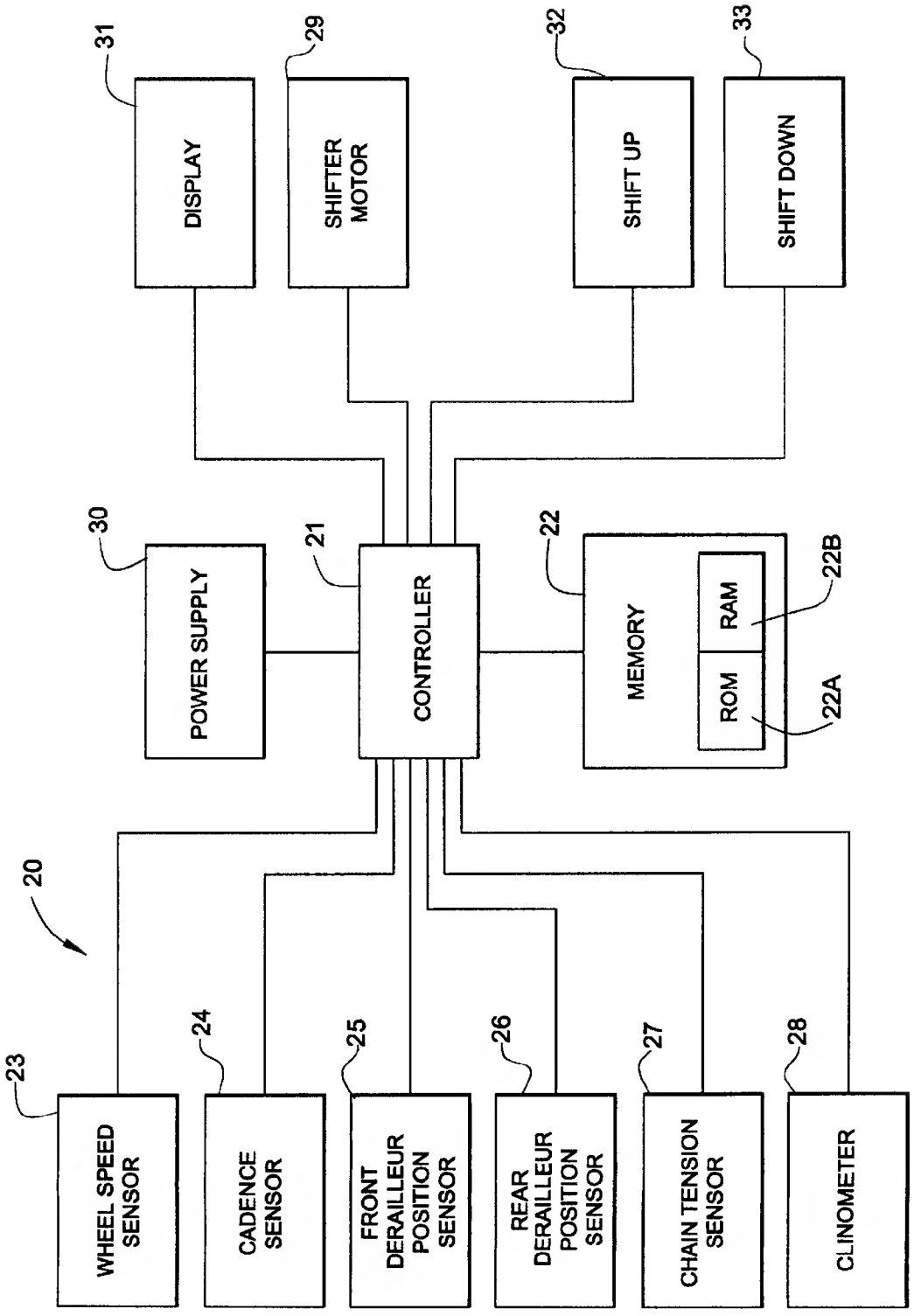

31
DISPLAY
29
SHIFTER MOTOR
32
SHIFT UP
33
SHIFT DOWN
30
POWER SUPPLY
21
CONTROLLER
22
MEMORY
RAM
22B
ROM
22A
20
23
WHEEL SPEED SENSOR
24
CADENCE SENSOR
25
FRONT DERAILLEUR POSITION SENSOR
26
REAR DERAILLEUR POSITION SENSOR
27
CHAIN TENSION SENSOR
28
CLINOMETER

FIG. 2

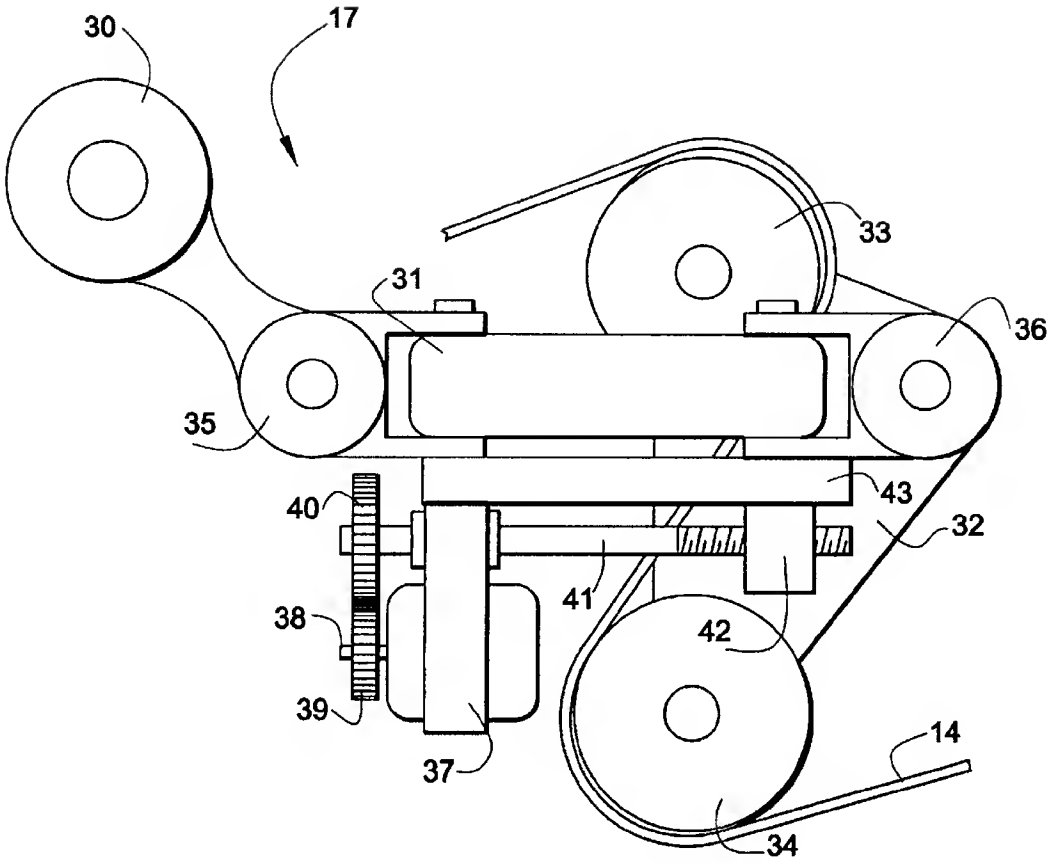

30
17
33
31
36
35
43
40
32
41
38
42
39
14
37
34

FIG. 3

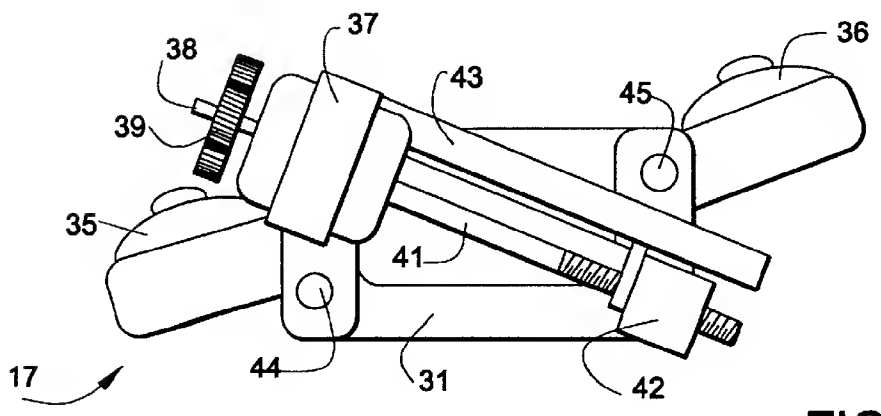

37
36
38
43
45
39
35
41
17
44
31
42

FIG. 4

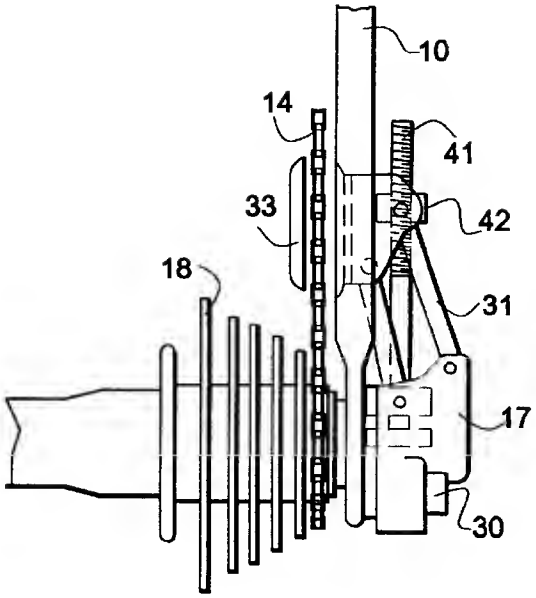


FIG. 5A

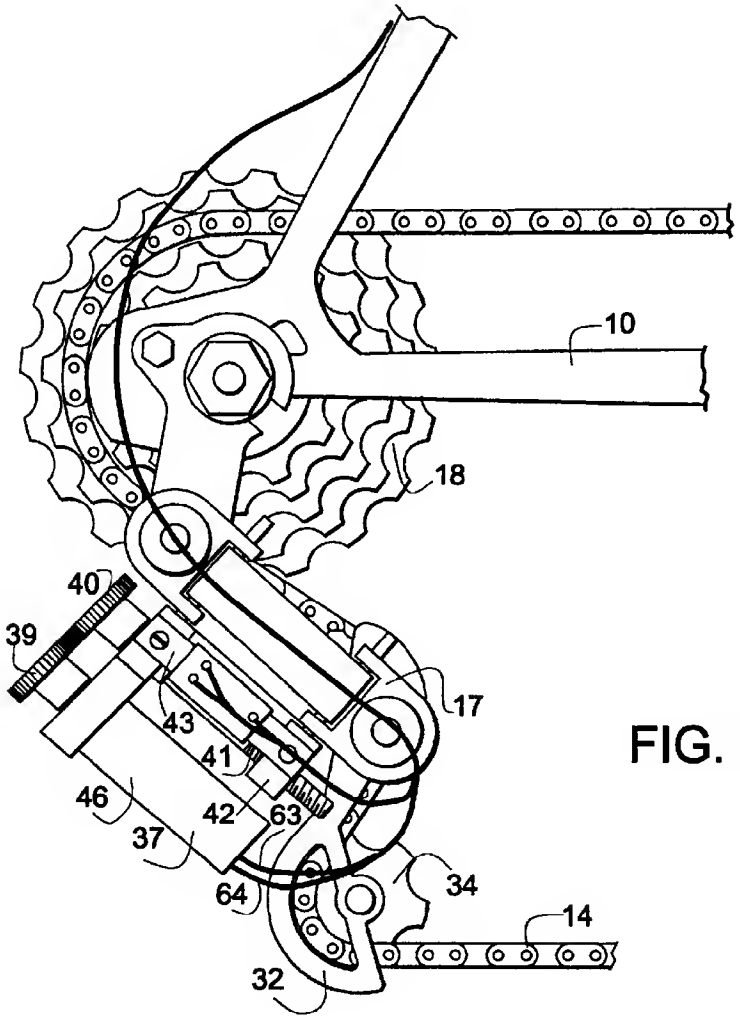


FIG. 5B

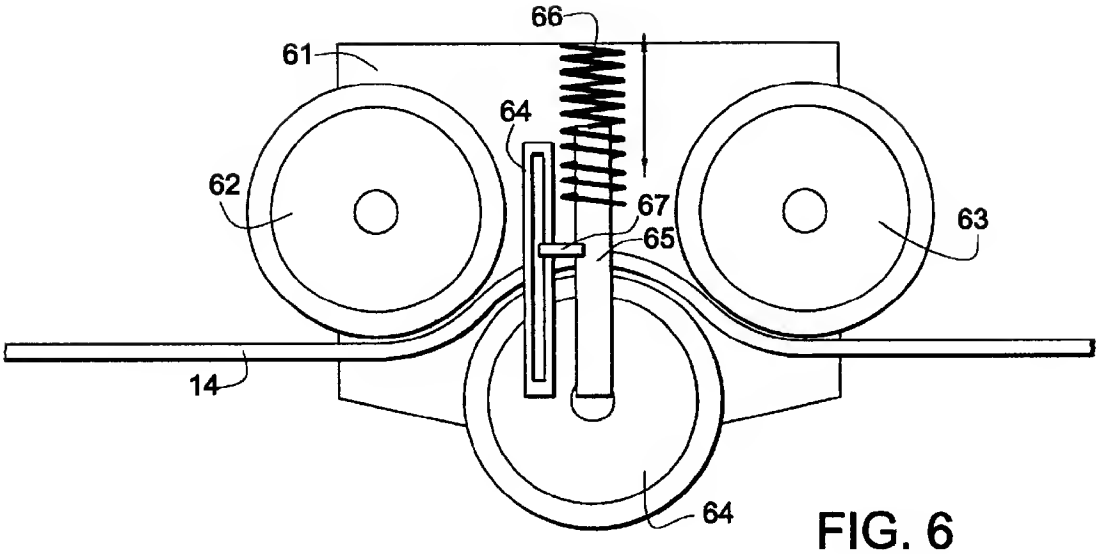


FIG. 6

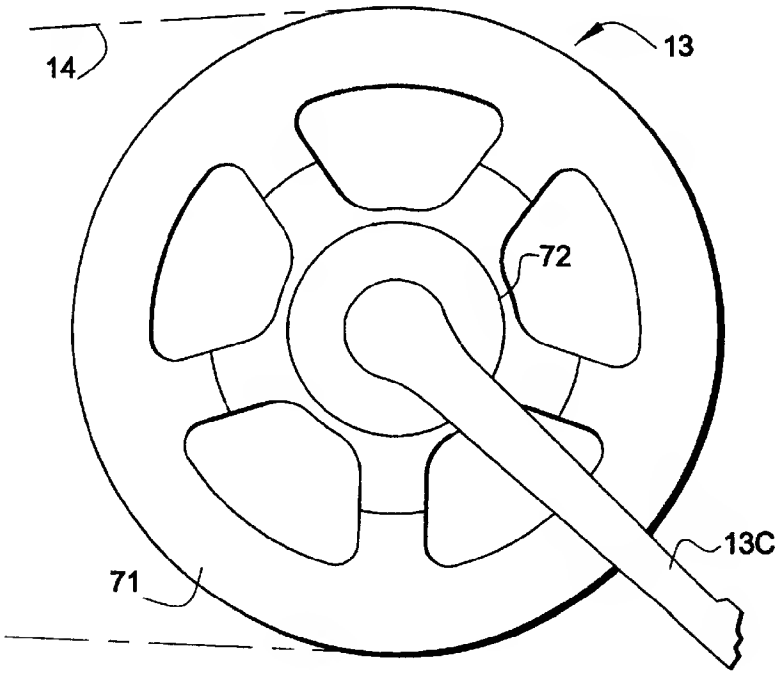


FIG. 7

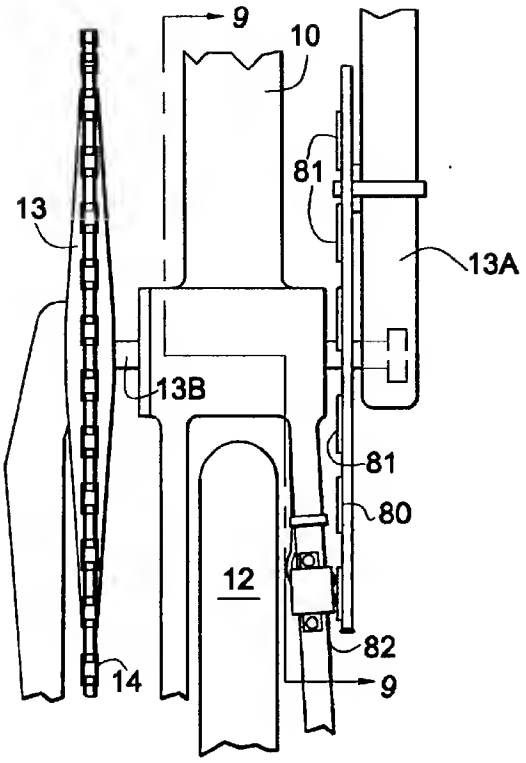

9
10
81
13
13A
13B
81
80
12
82
14
9

FIG. 8

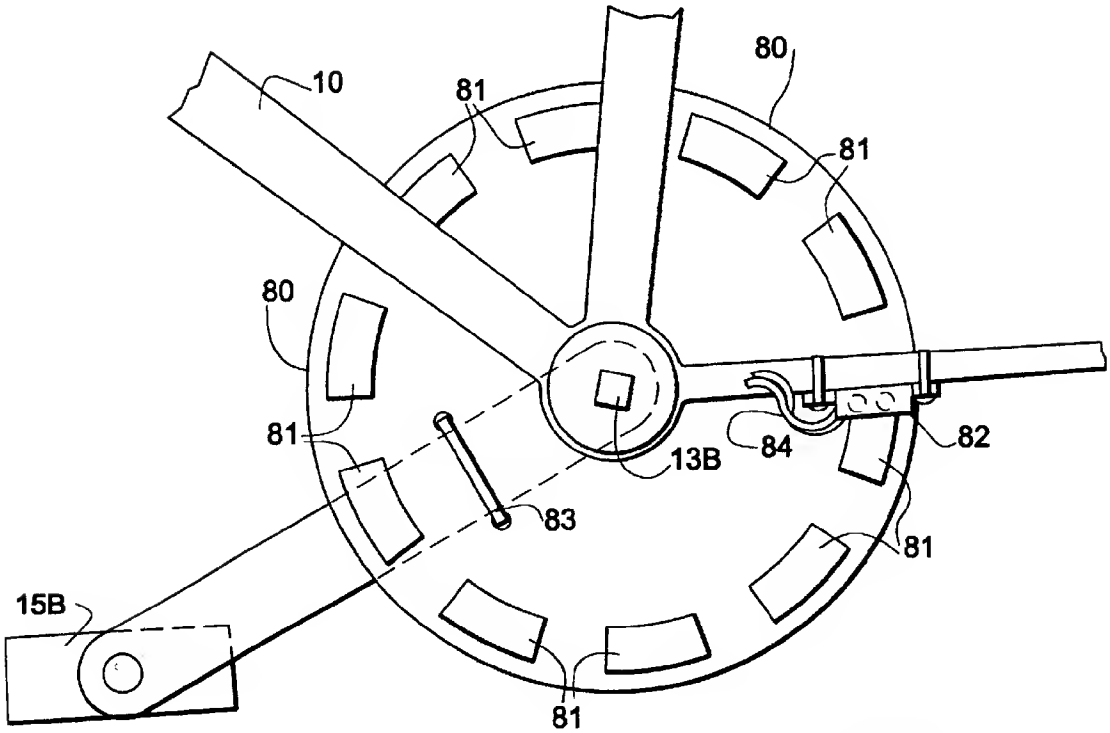

10
81
80
81
80
81
84
82
13B
83
81
15B
81

FIG. 9

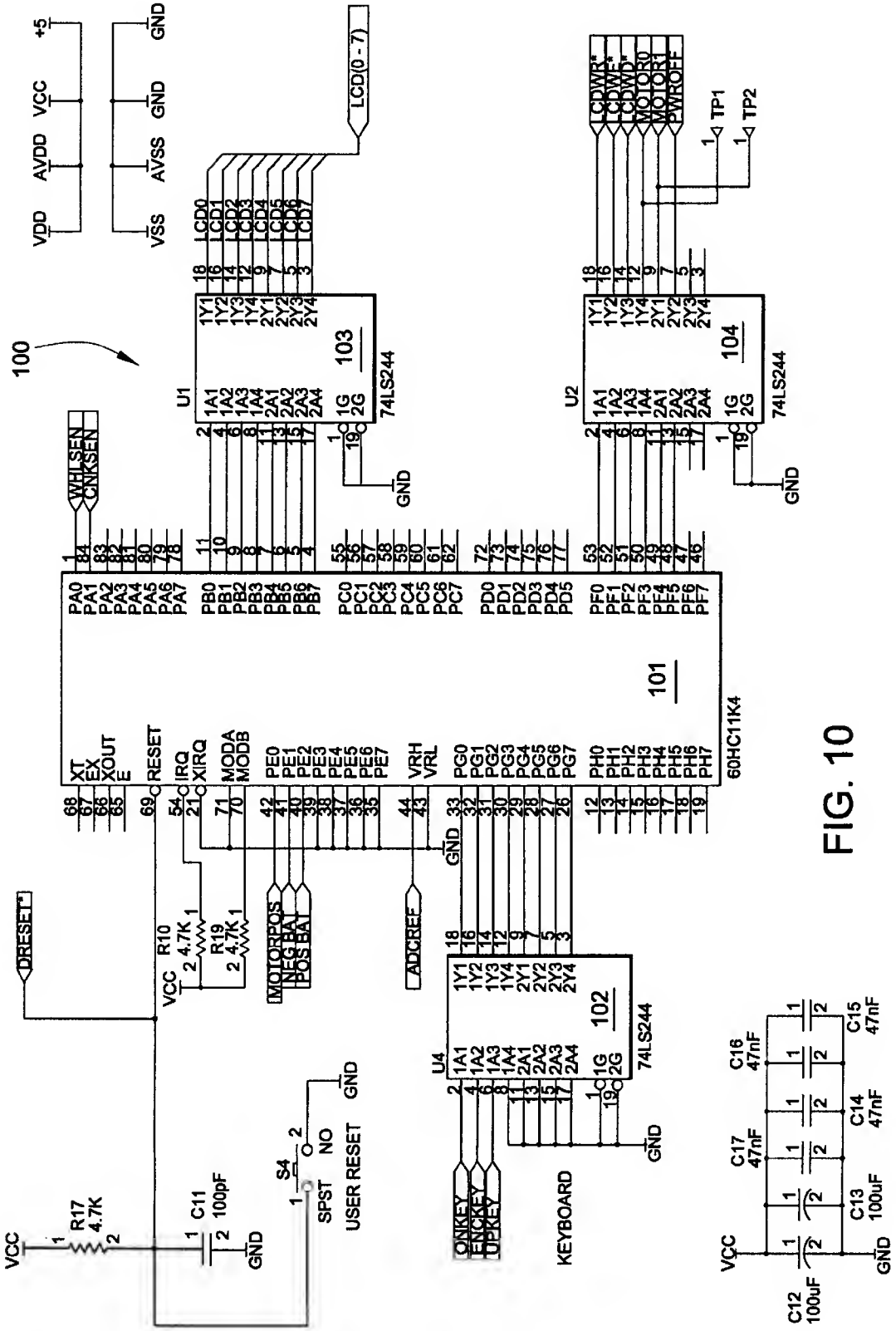

100
101
60HC11K4
102
103
104
74LS244
U1
U2
U4
LCD(0 - 7)
LCD0
LCD1
LCD2
LCD3
LCD4
LCD5
LCD6
LCD7
LCDWR*
LCDWE*
LCDWD*
MOTOR0
MOTOR1
PWROFF
TP1
TP2
+5
VDD
AVDD
VCC
VSS
AVSS
GND
WHLSEN
CNKSEN
DRESET*
R10 4.7K
R19 4.7K
R17 4.7K
C11 100pF
S4
SPST
NO
USER RESET
MOTORPOS
NEG BAT
POS BAT
ADCREF
ONKEY
ENCKEY
UPKEY
KEYBOARD
C12 100uF
C13 100uF
C14 47nF
C15 47nF
C16 47nF
C17 47nF

FIG. 10

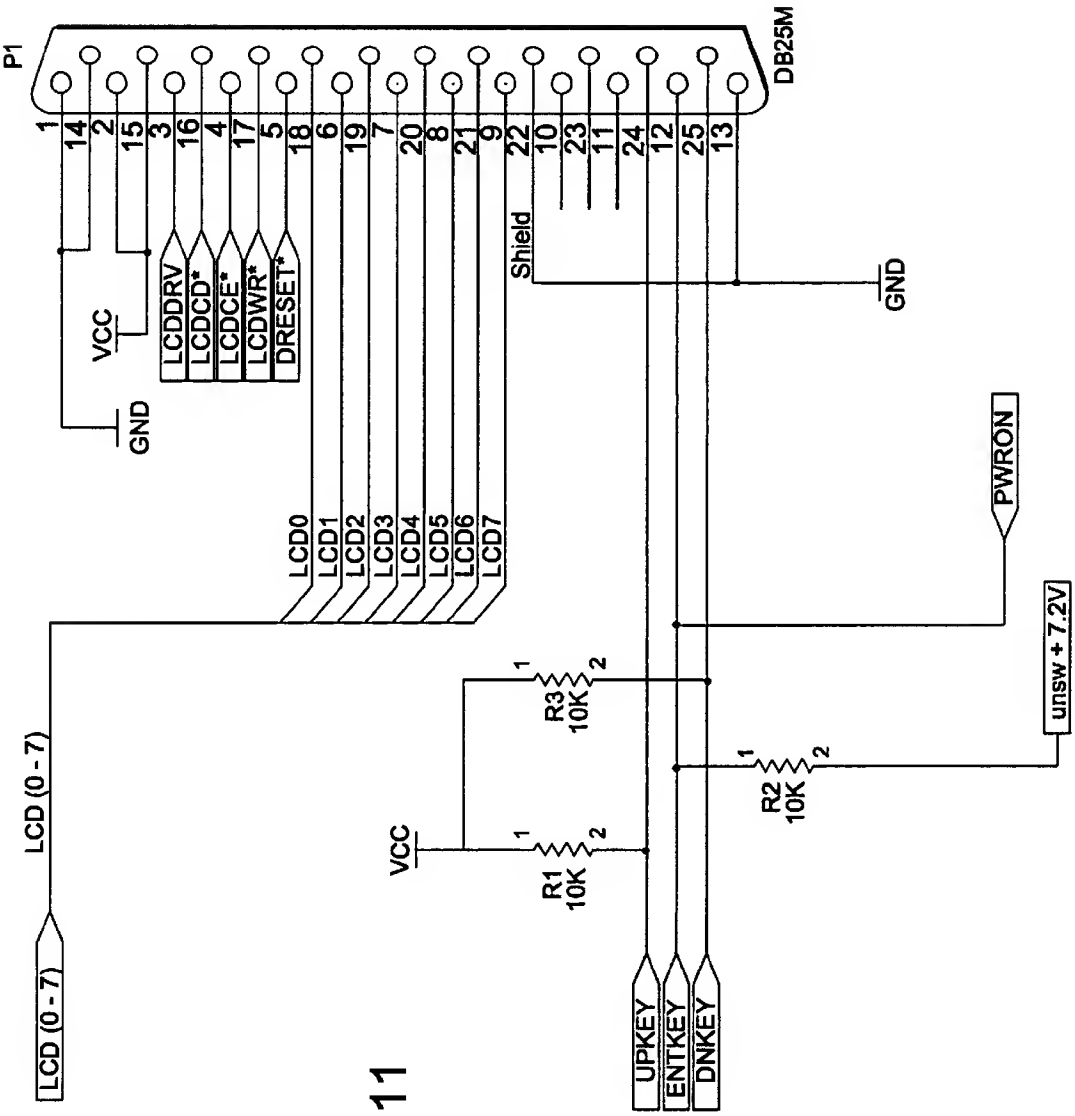

P1
DB25M
1
14
2
15
3
16
4
17
5
18
6
19
7
20
8
21
9
22
10
23
11
24
12
25
13
VCC
GND
LCDDRV
LCDCD*
LCDCE*
LCDWR*
DRESET*
Shield
GND
LCD0
LCD1
LCD2
LCD3
LCD4
LCD5
LCD6
LCD7
PWRON
unsw + 7.2V
LCD (0 - 7)
LCD (0 - 7)
R3
10K
R2
10K
R1
10K
VCC
UPKEY
ENTKEY
DNKEY

FIG. 11

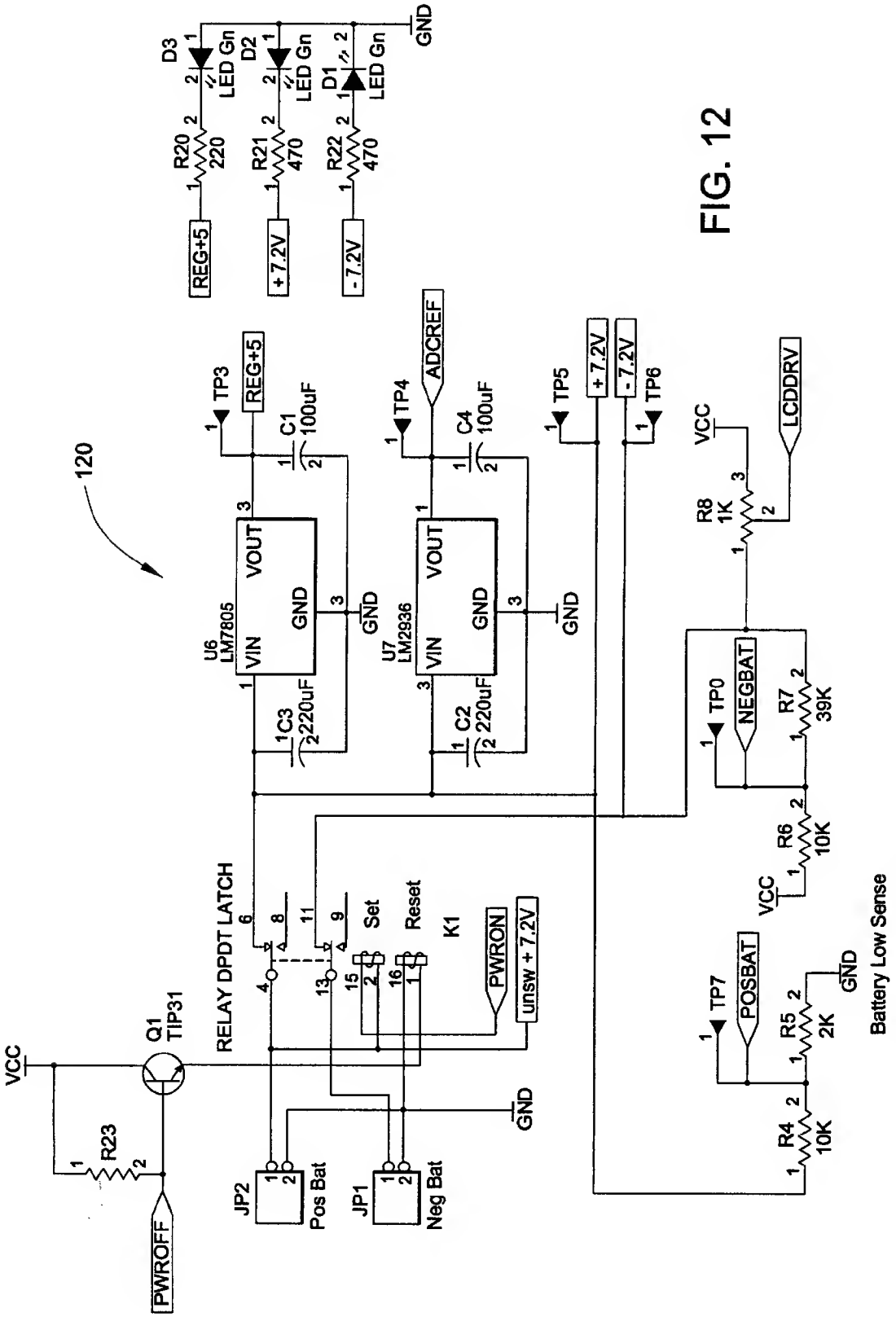

120
D3
LED Gn
D2
LED Gn
D1
LED Gn
GND
R20
220
R21
470
R22
470
REG+5
+7.2V
-7.2V
TP3
REG+5
C1
100uF
TP4
ADCREF
C4
100uF
TP5
+7.2V
-7.2V
TP6
VCC
LCDDRV
R8
1K
U6
LM7805
VIN
VOUT
GND
U7
LM2936
VIN
VOUT
GND
C3
220uF
C2
220uF
TP0
NEGBAT
R7
39K
R6
10K
VCC
TP7
POSBAT
R5
2K
GND
Battery Low Sense
R4
10K
Q1
TIP31
RELAY DPDT LATCH
K1
Set
Reset
PWRON
unsw + 7.2V
VCC
R23
PWROFF
JP2
Pos Bat
JP1
Neg Bat
GND

FIG. 12

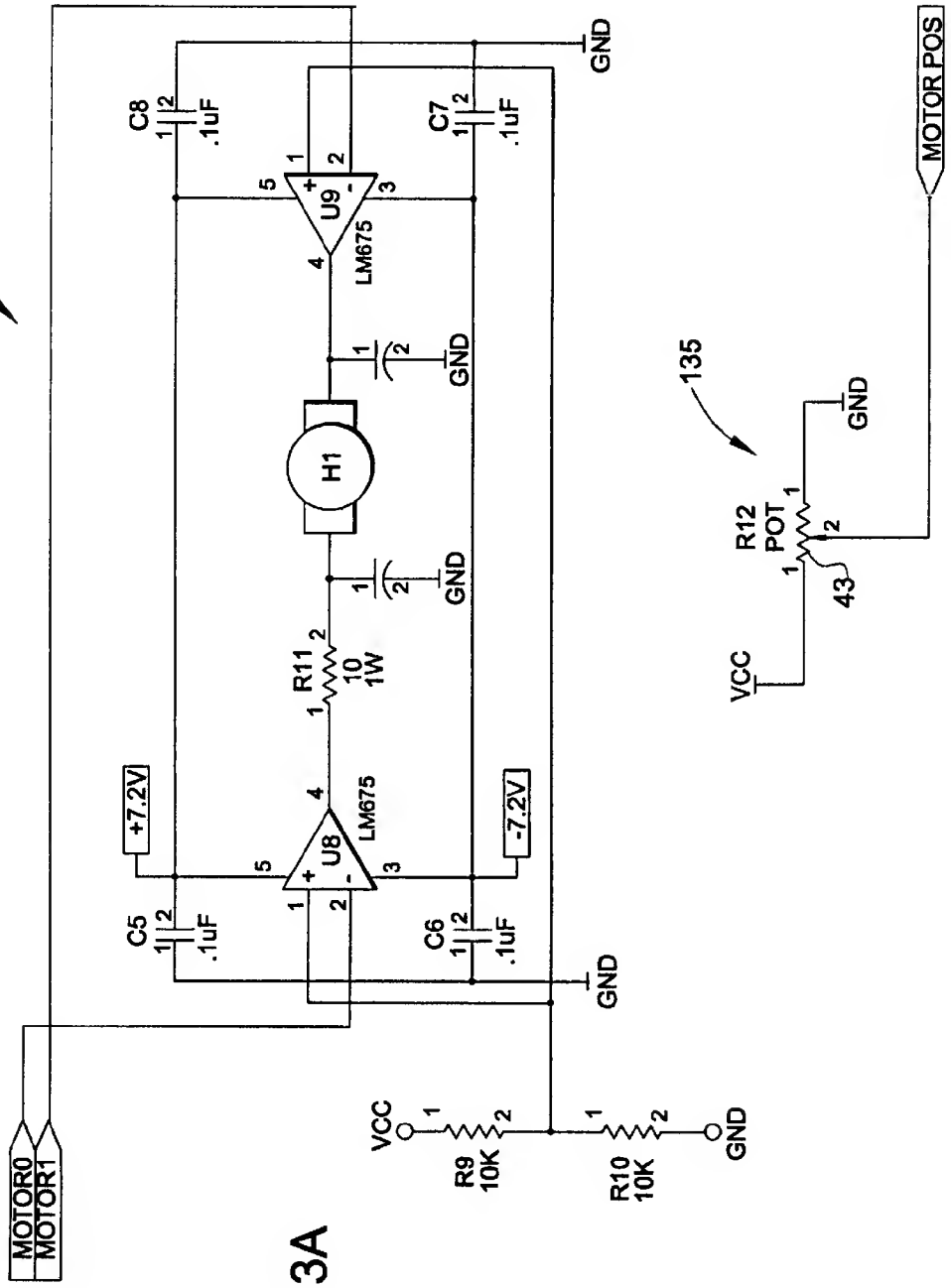


FIG. 13A

FIG. 13B

FIG. 14

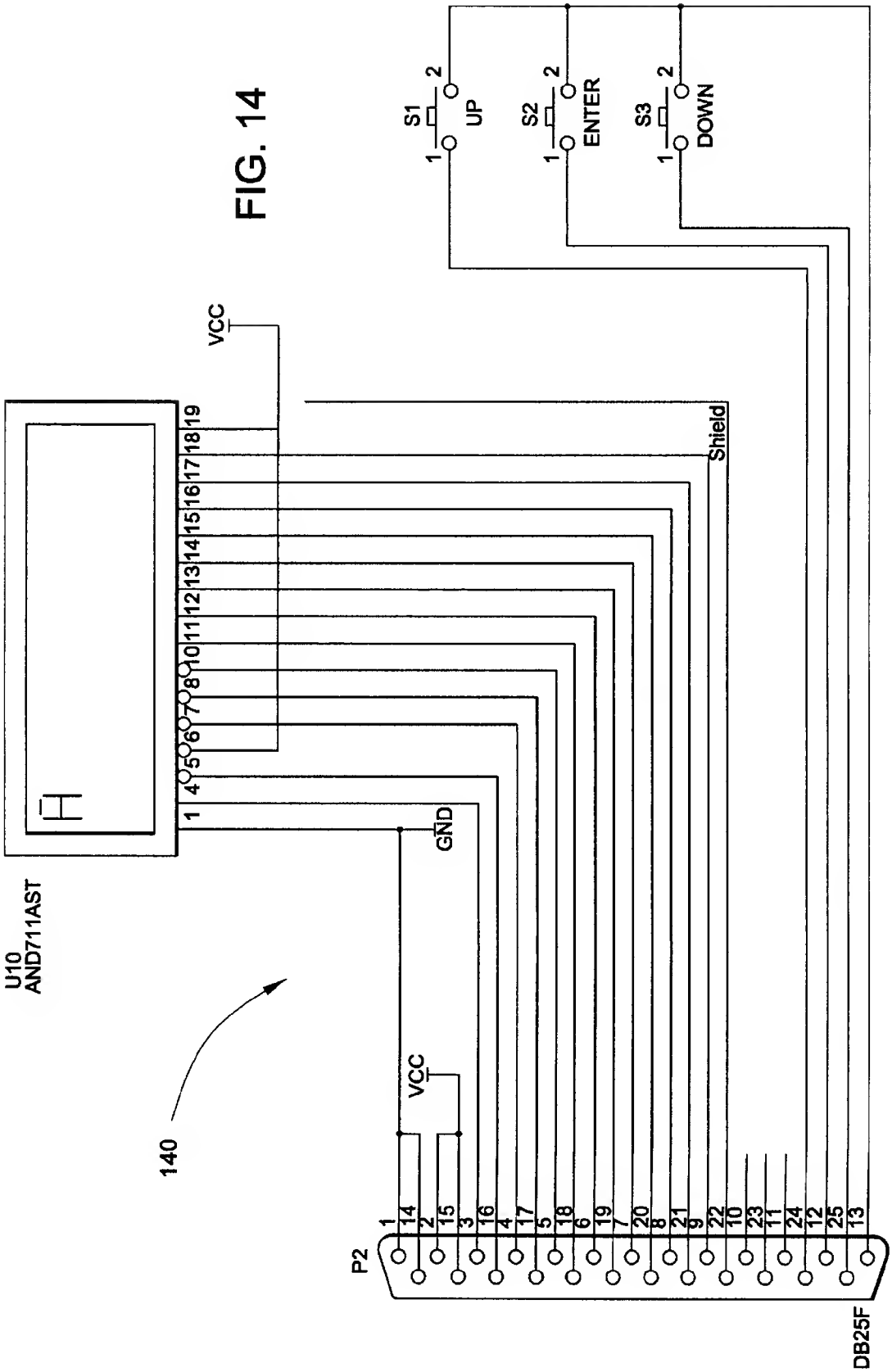
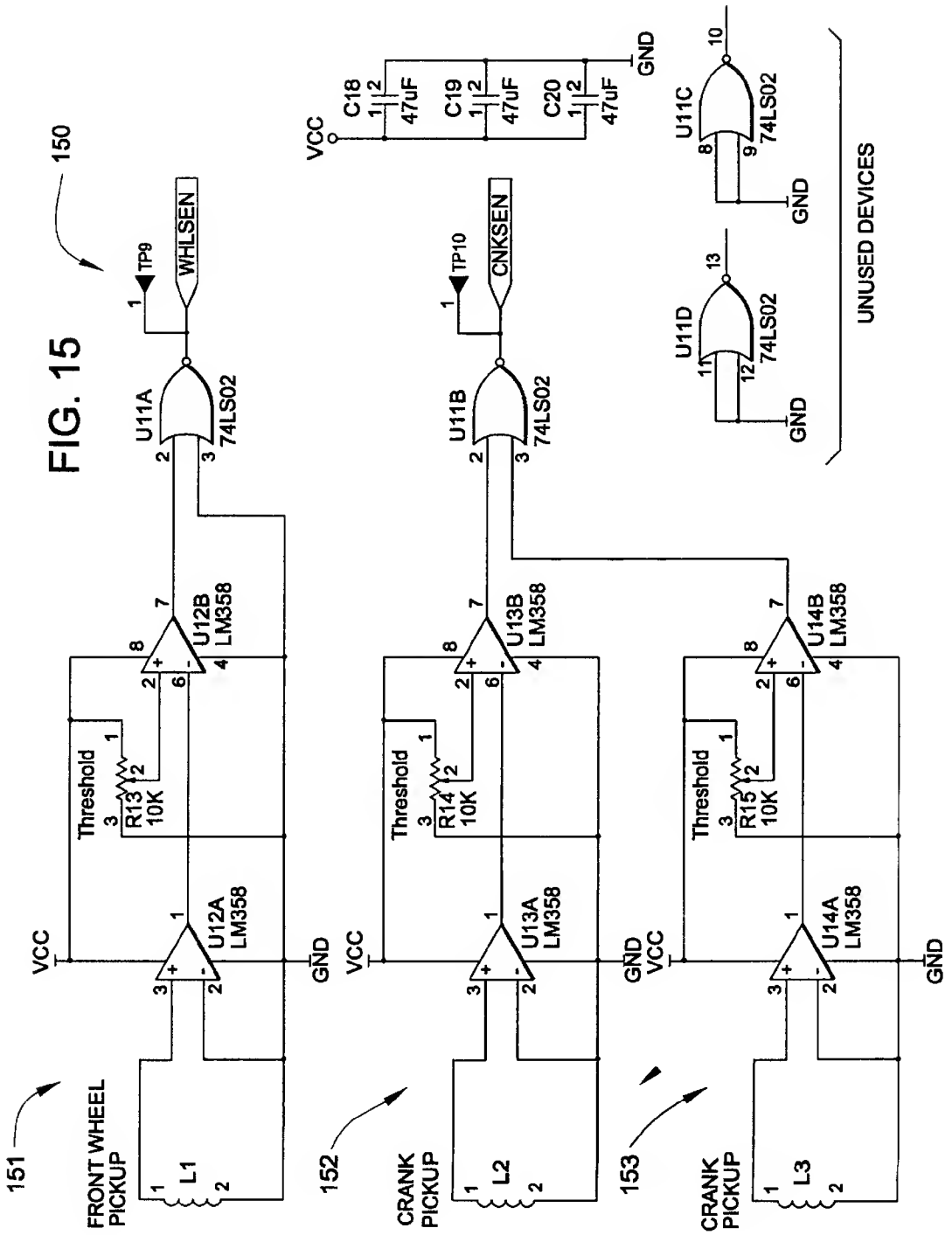

S1
UP
S2
ENTER
S3
DOWN
VCC
Shield
GND
U10
AND711AST
140
P2
DB25F

FIG. 15


150
WHLSEN
TP9
CNKSEN
TP10
VCC
GND
C18
47uF
C19
47uF
C20
47uF
U11A
74LS02
U11B
74LS02
U11C
74LS02
U11D
74LS02
UNUSED DEVICES
U12A
LM358
U12B
LM358
U13A
LM358
U13B
LM358
U14A
LM358
U14B
LM358
Threshold
R13
10K
R14
10K
R15
10K
151
FRONT WHEEL
PICKUP
L1
152
CRANK
PICKUP
L2
153
CRANK
PICKUP
L3

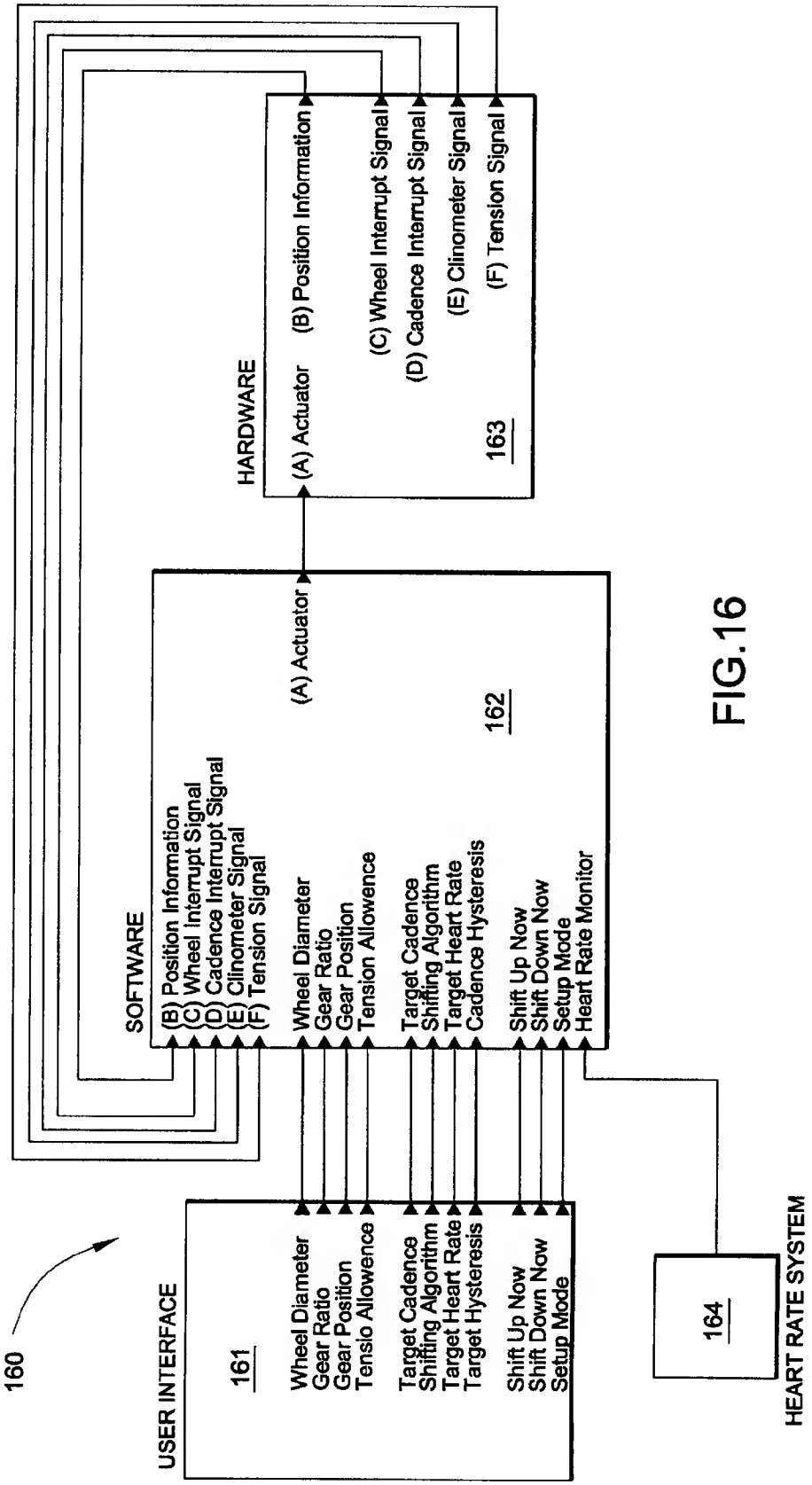

160
USER INTERFACE
161
Wheel Diameter
Gear Ratio
Gear Position
Tensio Allowence
Target Cadence
Shifting Algorithm
Target Heart Rate
Target Hysteresis
Shift Up Now
Shift Down Now
Setup Mode
SOFTWARE
(B) Position Information
(C) Wheel Interrupt Signal
(D) Cadence Interrupt Signal
(E) Clinometer Signal
(F) Tension Signal
Wheel Diameter
Gear Ratio
Gear Position
Tension Allowence
Target Cadence
Shifting Algorithm
Target Heart Rate
Cadence Hysteresis
Shift Up Now
Shift Down Now
Setup Mode
Heart Rate Monitor
(A) Actuator
162
HARDWARE
(A) Actuator
(B) Position Information
(C) Wheel Interrupt Signal
(D) Cadence Interrupt Signal
(E) Clinometer Signal
(F) Tension Signal
163
164
HEART RATE SYSTEM

FIG.16

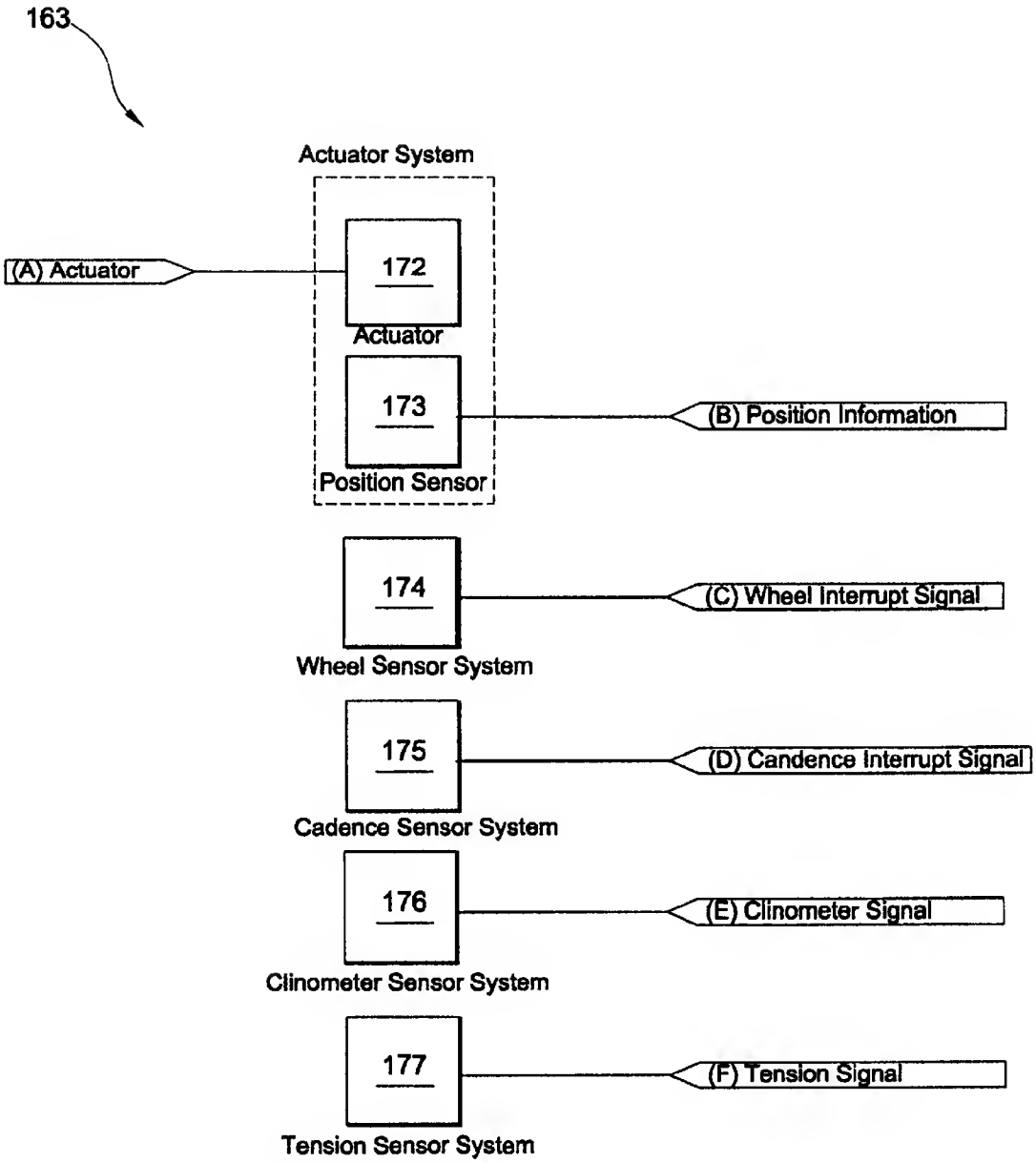

163
Actuator System
(A) Actuator
172
Actuator
173
Position Sensor
(B) Position Information
174
Wheel Sensor System
(C) Wheel Interrupt Signal
175
Cadence Sensor System
(D) Candence Interrupt Signal
176
Clinometer Sensor System
(E) Clinometer Signal
177
Tension Sensor System
(F) Tension Signal

FIG. 17

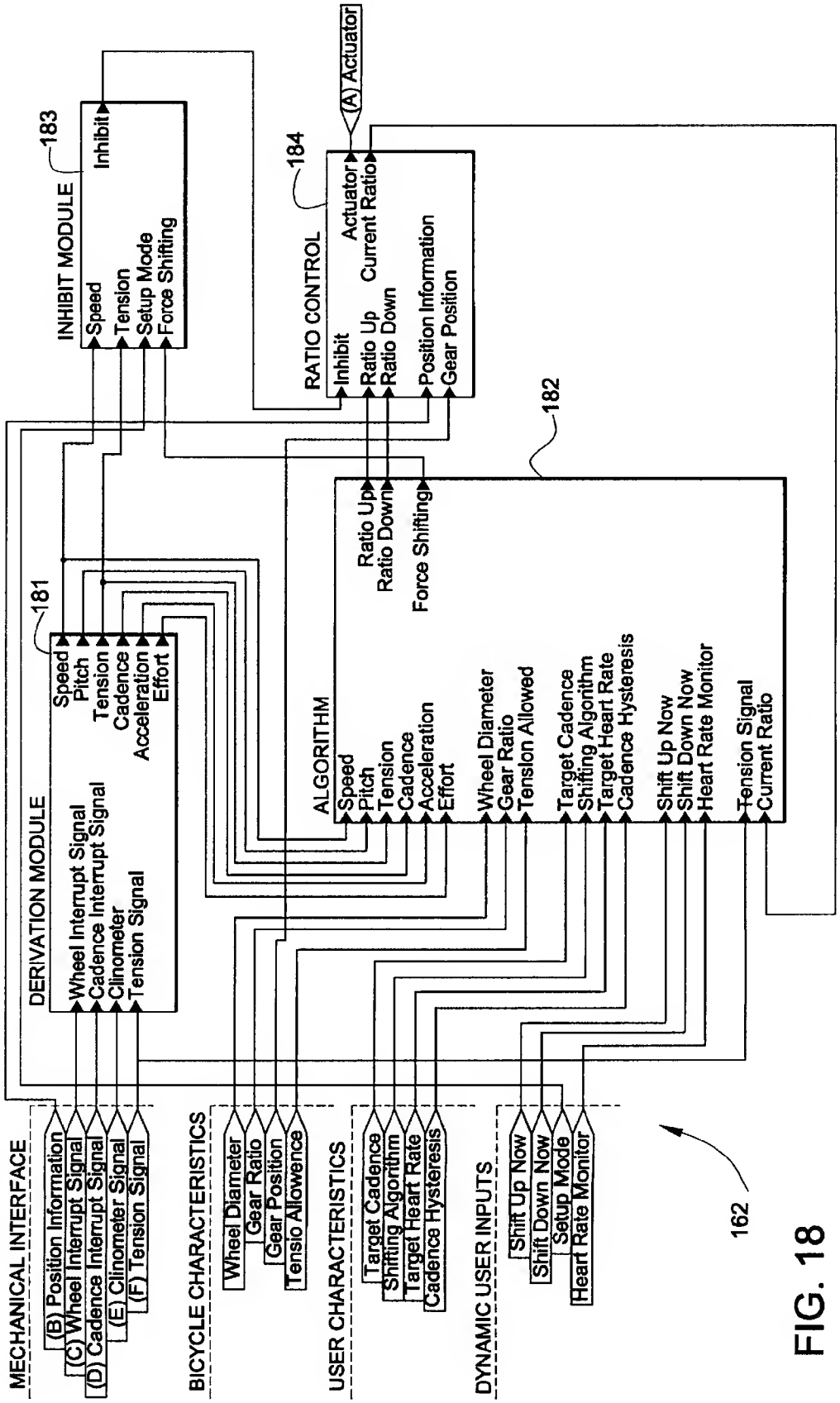

MECHANICAL INTERFACE
(B) Position Information
(C) Wheel Interrupt Signal
(D) Cadence Interrupt Signal
(E) Clinometer Signal
(F) Tension Signal
BICYCLE CHARACTERISTICS
Wheel Diameter
Gear Ratio
Gear Position
Tensio Allowence
USER CHARACTERISTICS
Target Cadence
Shifting Algorithm
Target Heart Rate
Cadence Hysteresis
DYNAMIC USER INPUTS
Shift Up Now
Shift Down Now
Setup Mode
Heart Rate Monitor
162
DERIVATION MODULE
181
Wheel Interrupt Signal
Cadence Interrupt Signal
Clinometer
Tension Signal
Speed
Pitch
Tension
Cadence
Acceleration
Effort
INHIBIT MODULE
183
Inhibit
Speed
Tension
Setup Mode
Force Shifting
RATIO CONTROL
184
Inhibit
Ratio Up
Ratio Down
Actuator
Current Ratio
Position Information
Gear Position
(A) Actuator
182
ALGORITHM
Speed
Pitch
Tension
Cadence
Acceleration
Effort
Wheel Diameter
Gear Ratio
Tenslon Allowed
Target Cadence
Shifting Algorithm
Target Heart Rate
Cadence Hysteresis
Shift Up Now
Shift Down Now
Heart Rate Monitor
Ratio Up
Ratio Down
Force Shifting
Tension Signal
Current Ratio

FIG. 18

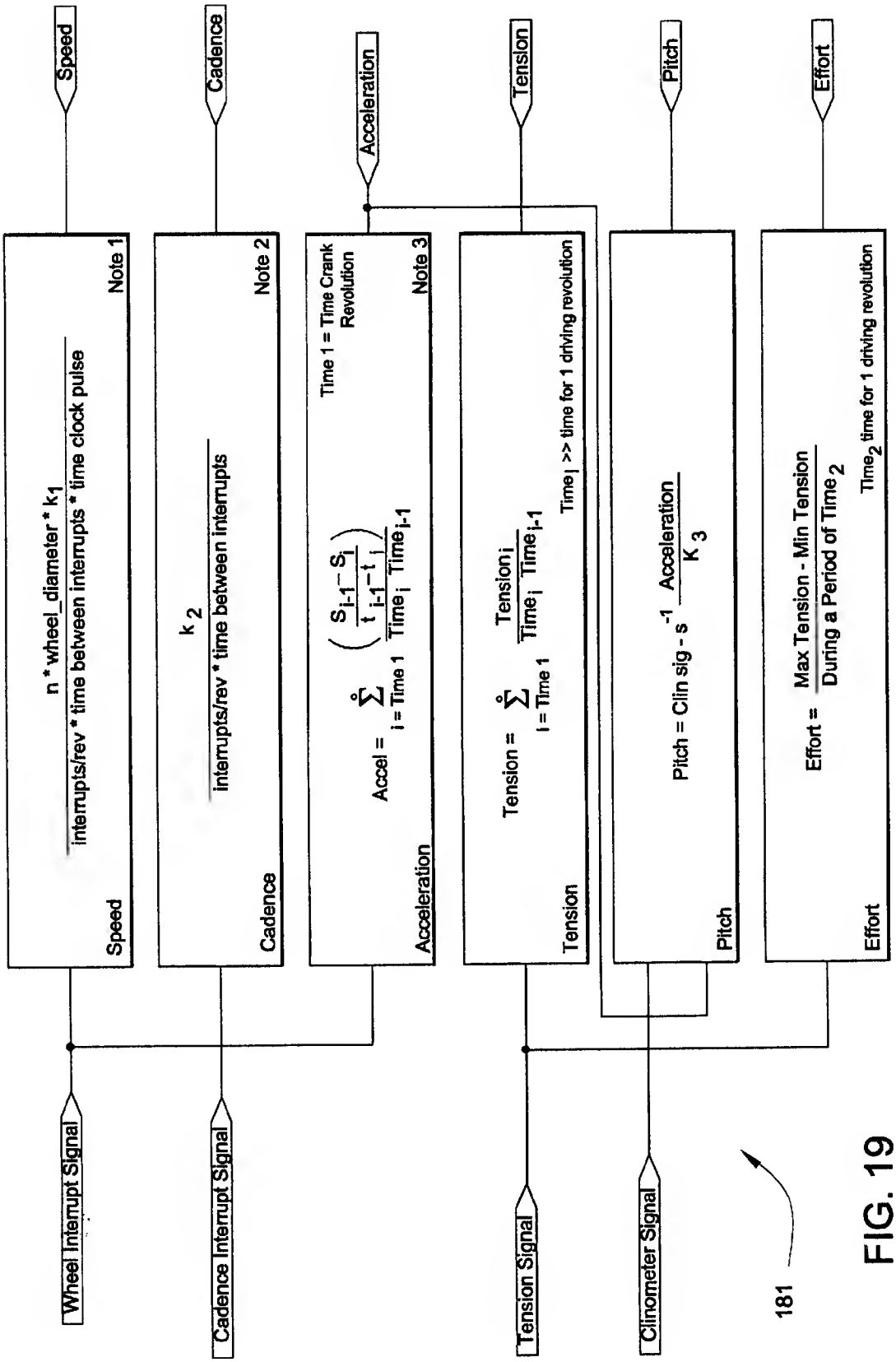

Speed
Cadence
Acceleration
Tension
Pitch
Effort
n * wheel_diameter * k1
interrupts/rev * time between interrupts * time clock pulse
Note 1
Speed
k 2
interrupts/rev * time between interrupts
Note 2
Cadence
Time 1 = Time Crank Revolution
Accel = Σ (Si-1 − Si) / (ti-1 − ti) / Timei Timei-1
i = Time 1
Note 3
Acceleration
Tension = Σ Tensioni / Timei Timei-1
i = Time 1
Timei >> time for 1 driving revolution
Tension
Pitch = Clin sig - s-1 Acceleration / K3
Pitch
Effort = Max Tension - Min Tension / During a Period of Time2
Time2 time for 1 driving revolution
Effort
Wheel Interrupt Signal
Cadence Interrupt Signal
Tension Signal
Clinometer Signal
181

FIG. 19

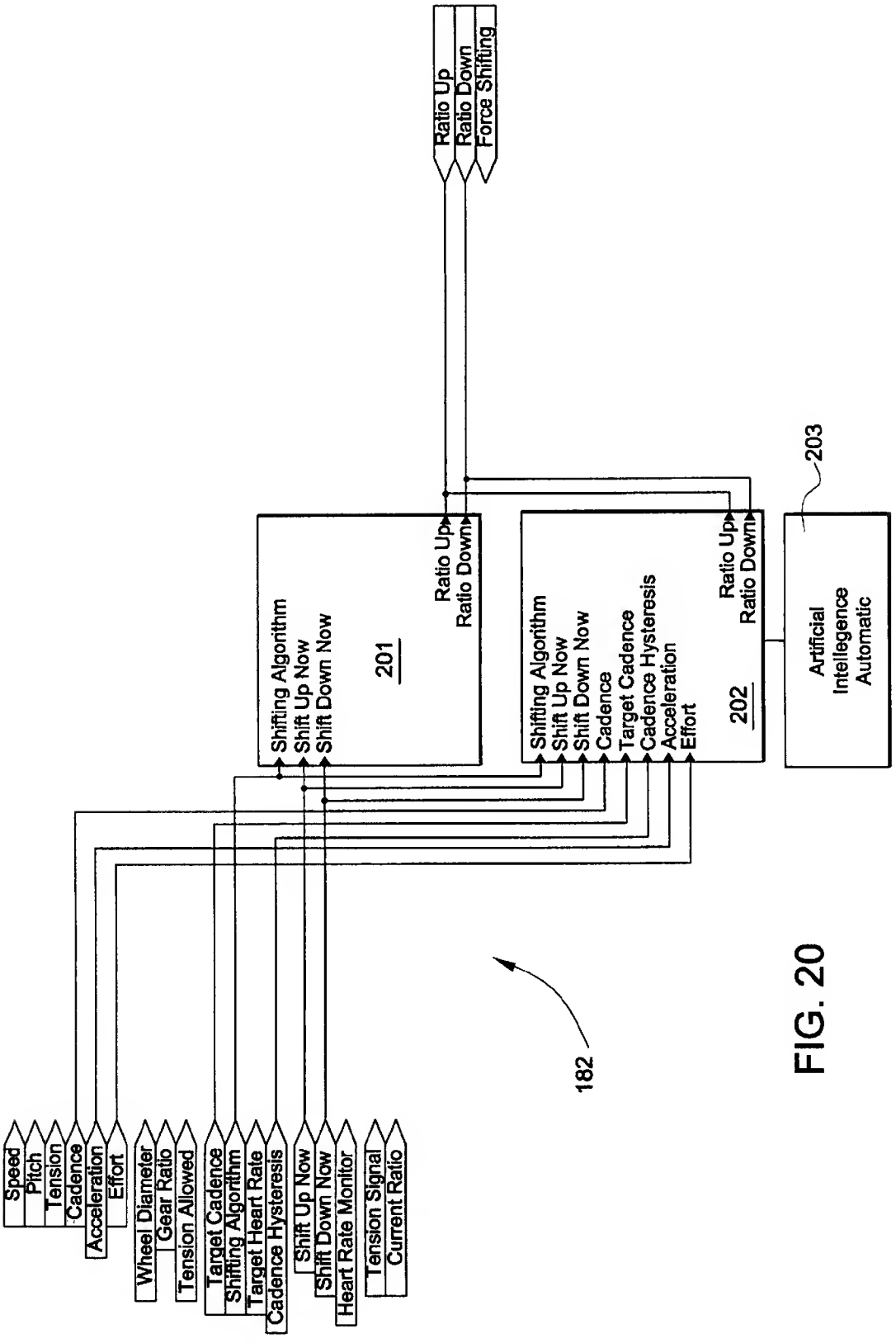
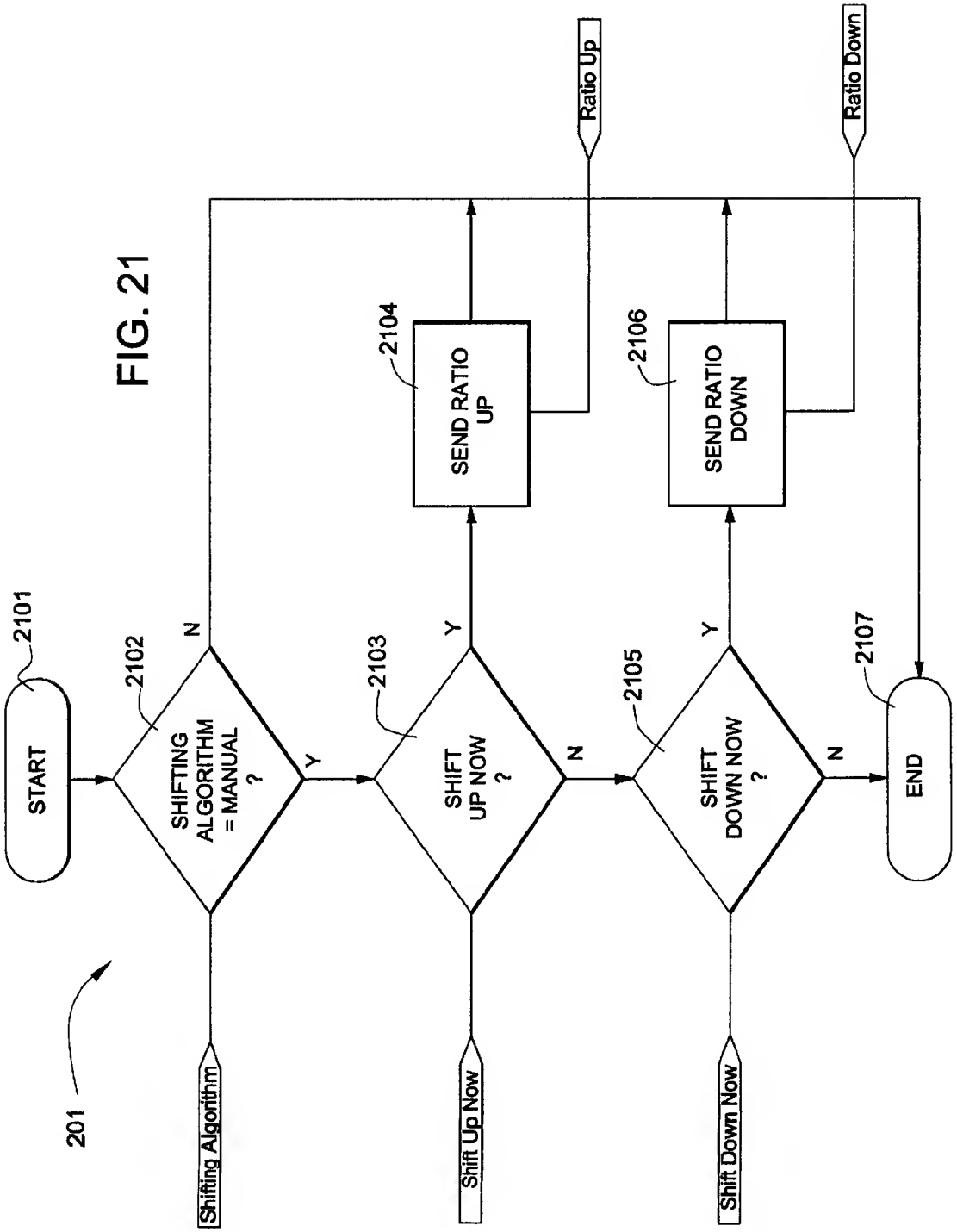
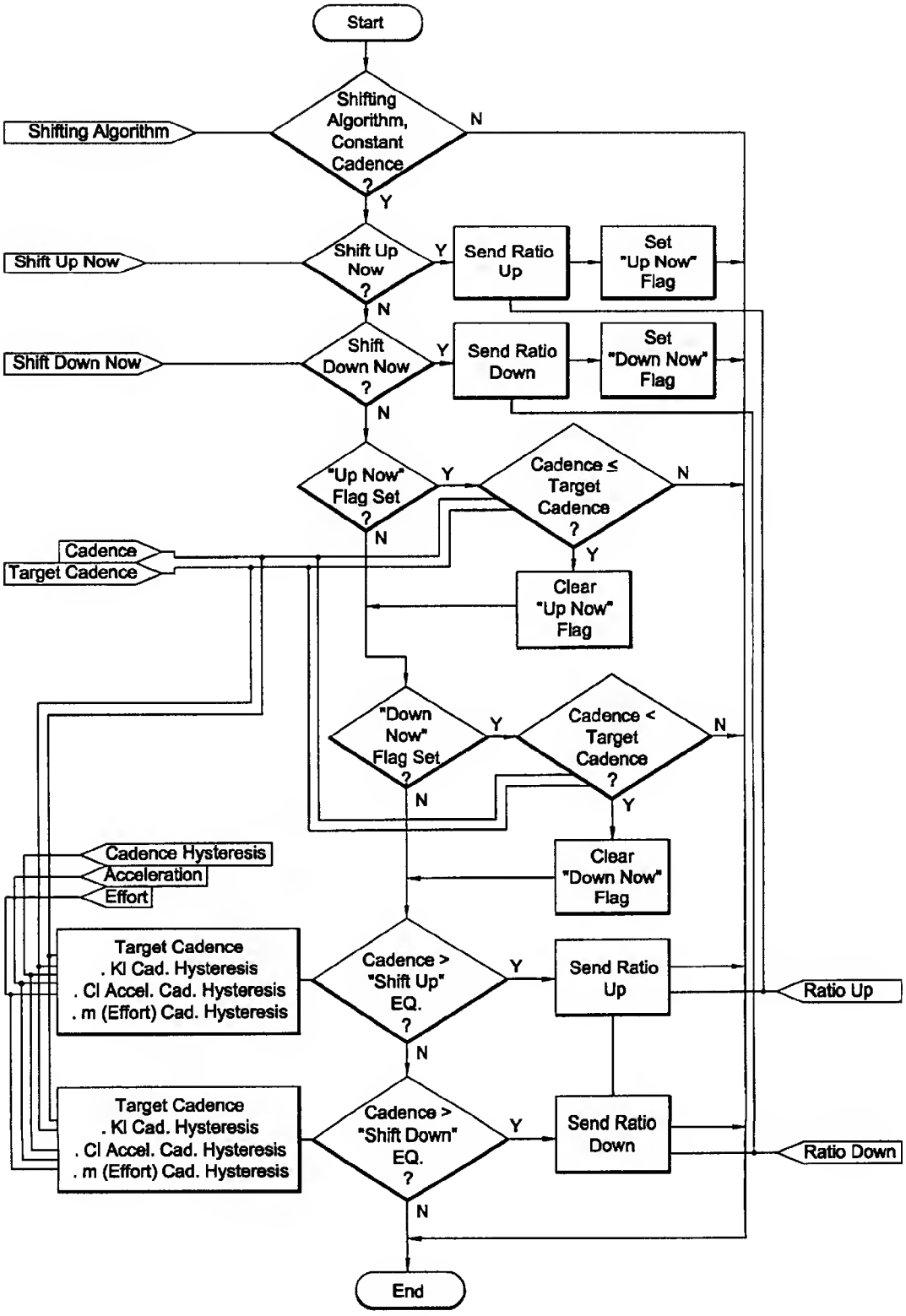

Ratio Up
Ratio Down
Force Shifting
203
Shifting Algorithm
Shift Up Now
Shift Down Now
201
Ratio Up
Ratio Down
Shifting Algorithm
Shift Up Now
Shift Down Now
Cadence
Target Cadence
Cadence Hysteresis
Acceleration
Effort
202
Ratio Up
Ratio Down
Artificial
Intellegence
Automatic
182
Speed
Pitch
Tension
Cadence
Acceleration
Effort
Wheel Diameter
Gear Ratio
Tension Allowed
Target Cadence
Shifting Algorithm
Target Heart Rate
Cadence Hysteresis
Shift Up Now
Shift Down Now
Heart Rate Monitor
Tension Signal
Current Ratio

FIG. 20

FIG. 21


201
2101
START
2102
SHIFTING ALGORITHM = MANUAL ?
N
Y
2103
SHIFT UP NOW ?
Y
N
2104
SEND RATIO UP
2105
SHIFT DOWN NOW ?
Y
N
2106
SEND RATIO DOWN
2107
END
Ratio Up
Ratio Down
Shifting Algorithm
Shift Up Now
Shift Down Now


Start
Shifting Algorithm
Shifting Algorithm, Constant Cadence ?
N
Y
Shift Up Now
Shift Up Now ?
Y
Send Ratio Up
Set "Up Now" Flag
N
Shift Down Now
Shift Down Now ?
Y
Send Ratio Down
Set "Down Now" Flag
N
"Up Now" Flag Set ?
Y
Cadence ≤ Target Cadence ?
N
N
Y
Cadence
Target Cadence
Clear "Up Now" Flag
"Down Now" Flag Set ?
Y
Cadence < Target Cadence ?
N
N
Y
Cadence Hysteresis
Acceleration
Effort
Clear "Down Now" Flag
Target Cadence
. Kl Cad. Hysteresis
. Cl Accel. Cad. Hysteresis
. m (Effort) Cad. Hysteresis
Cadence > "Shift Up" EQ. ?
Y
Send Ratio Up
Ratio Up
N
Target Cadence
. Kl Cad. Hysteresis
. Cl Accel. Cad. Hysteresis
. m (Effort) Cad. Hysteresis
Cadence > "Shift Down" EQ. ?
Y
Send Ratio Down
Ratio Down
N
End

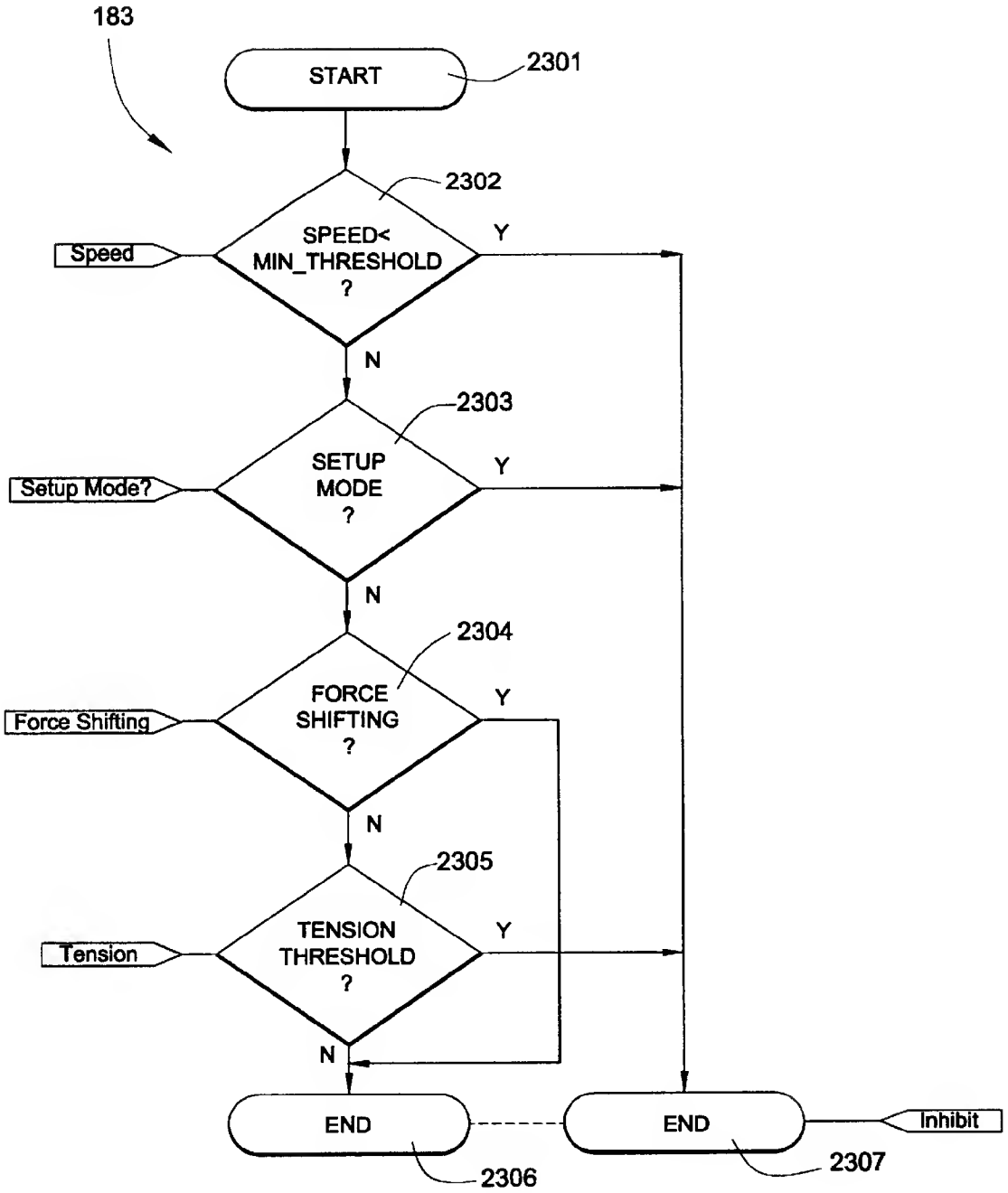

183
START
2301
2302
SPEED< MIN_THRESHOLD ?
Speed
Y
N
2303
SETUP MODE ?
Setup Mode?
Y
N
2304
FORCE SHIFTING ?
Force Shifting
Y
N
2305
TENSION THRESHOLD ?
Tension
Y
N
END
2306
END
Inhibit
2307

FIG. 23

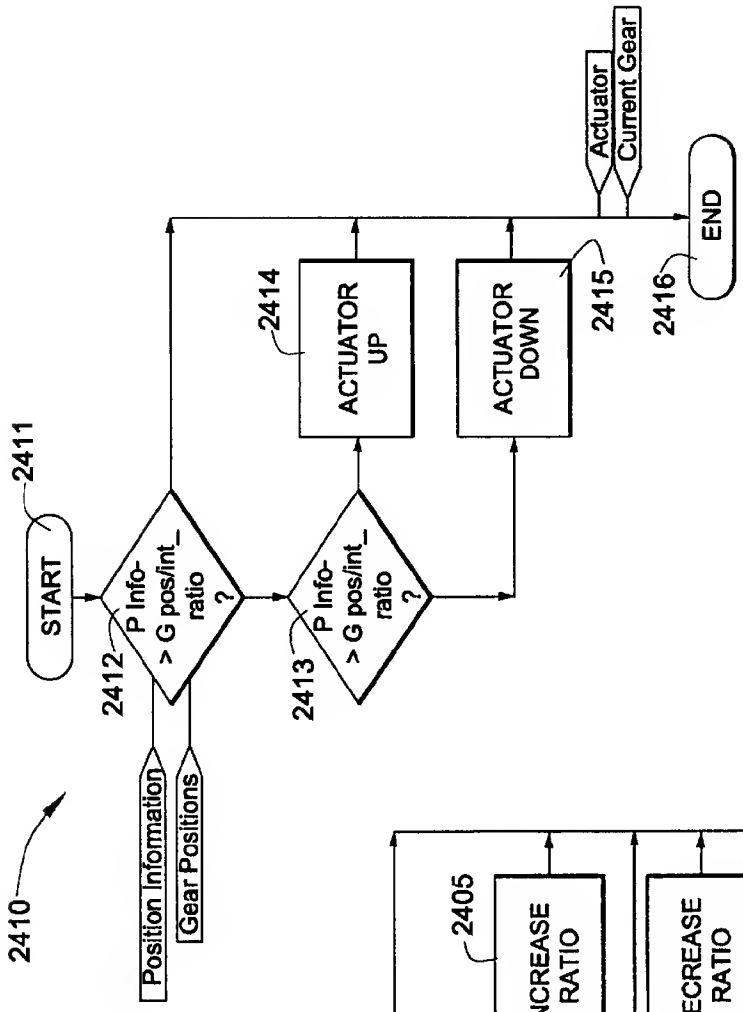


FIG. 24B

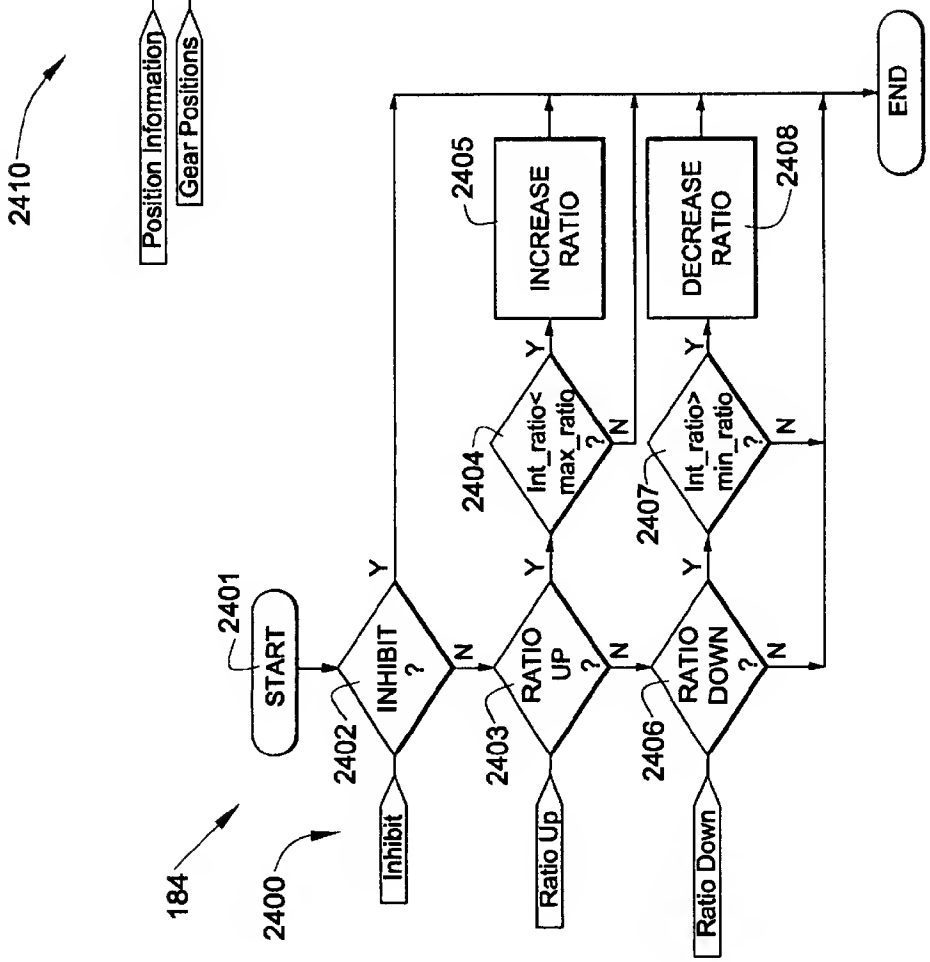


FIG. 24A

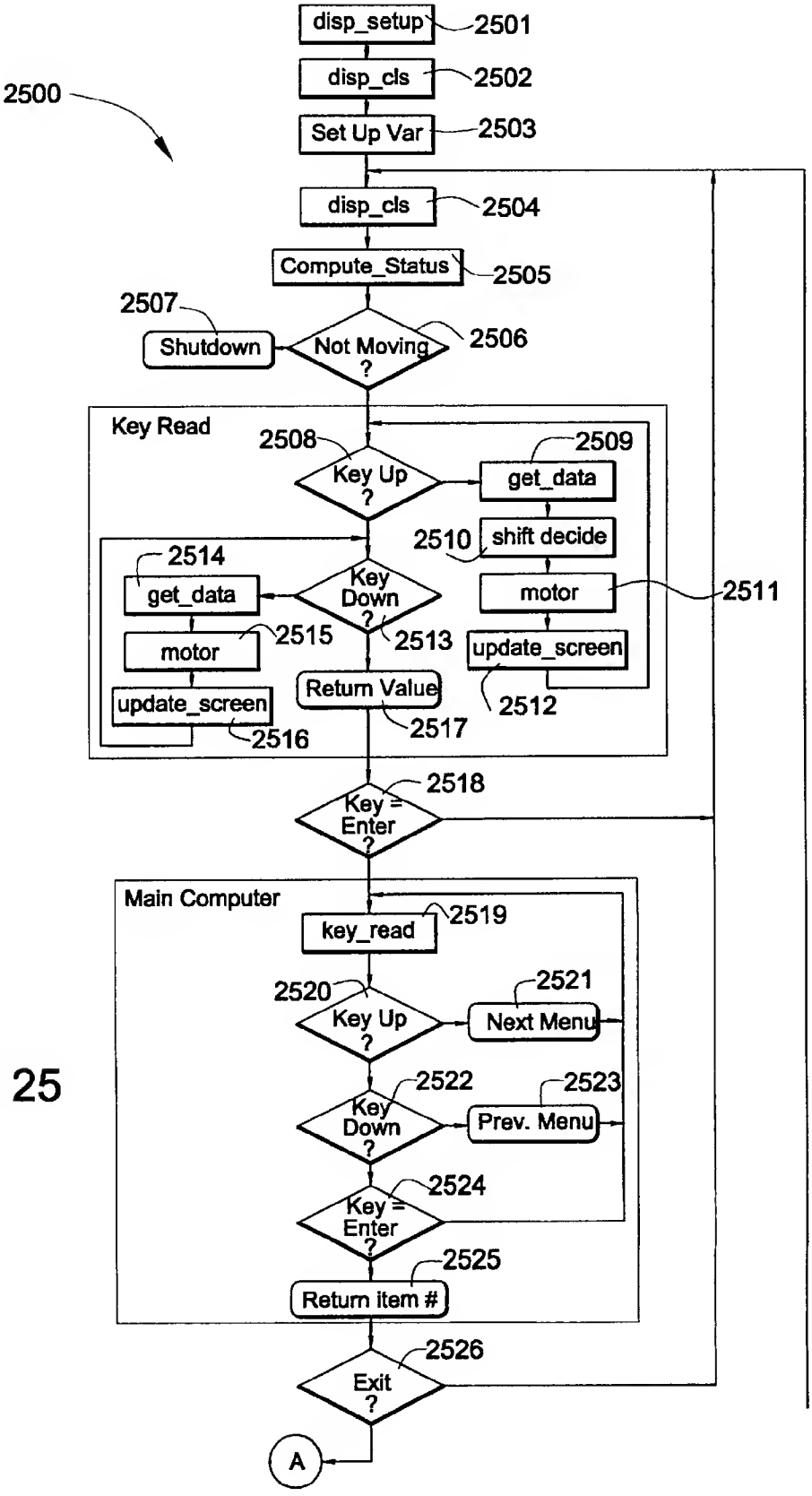

2500
disp_setup
2501
disp_cls
2502
Set Up Var
2503
disp_cls
2504
Compute_Status
2505
2507
Shutdown
Not Moving ?
2506
Key Read
2508
Key Up ?
2509
get_data
2510
shift decide
2514
get_data
Key Down ?
motor
2511
motor
2515
2513
update_screen
update_screen
Return Value
2512
2516
2517
2518
Key = Enter ?
Main Computer
key_read
2519
2520
Key Up ?
2521
Next Menu
2522
2523
Key Down ?
Prev. Menu
2524
Key = Enter ?
2525
Return item #
2526
Exit ?
A

FIG. 25

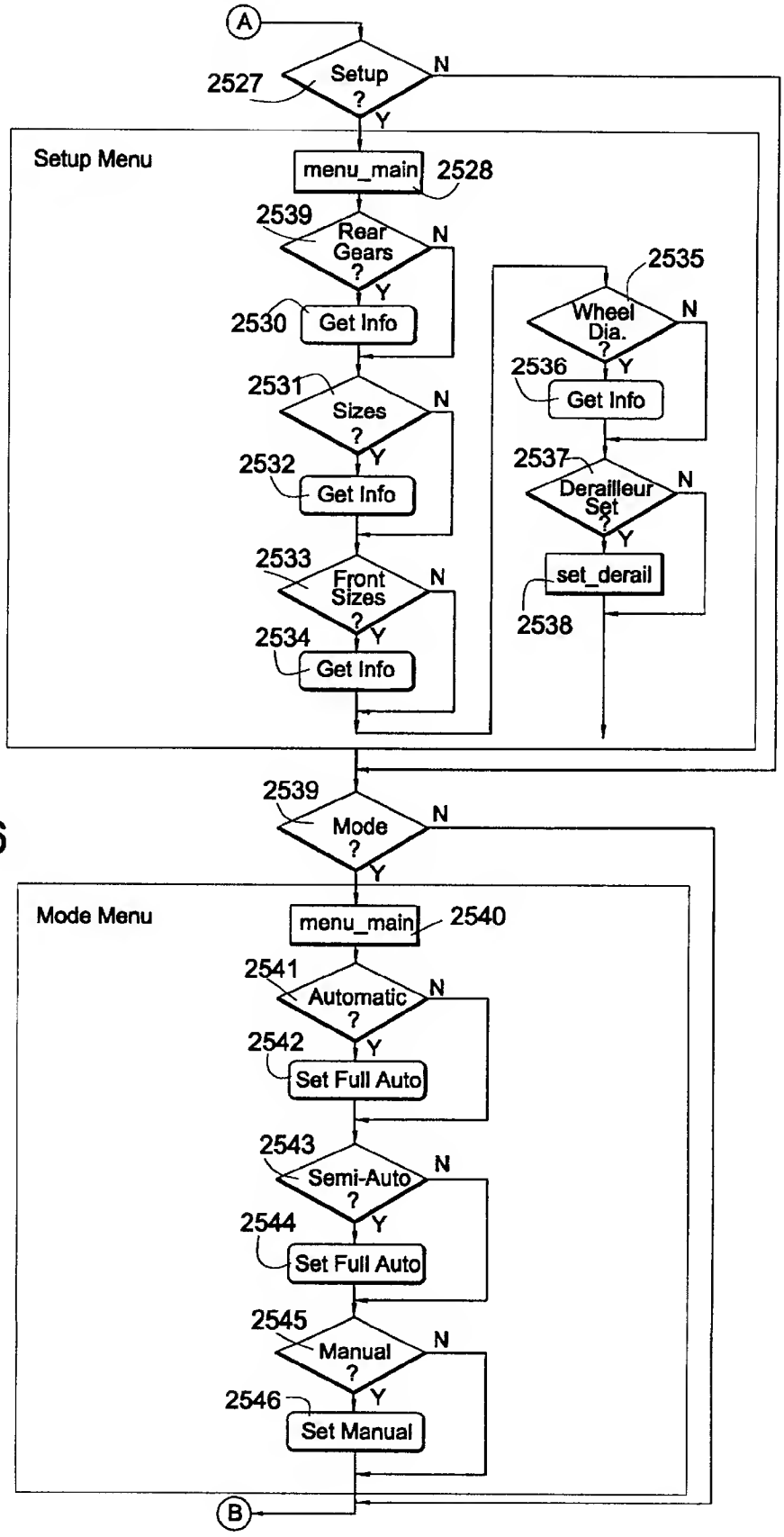

A
Setup ?
2527
N
Y
Setup Menu
menu_main
2528
2539
Rear Gears ?
N
Y
2530
Get Info
2531
Sizes ?
N
Y
2532
Get Info
2533
Front Sizes ?
N
Y
2534
Get Info
2535
Wheel Dia. ?
N
Y
2536
Get Info
2537
Derailleur Set ?
N
Y
set_derail
2538
2539
Mode ?
N
Y
Mode Menu
menu_main
2540
2541
Automatic ?
N
Y
2542
Set Full Auto
2543
Semi-Auto ?
N
Y
2544
Set Full Auto
2545
Manual ?
N
Y
2546
Set Manual
B

FIG. 26

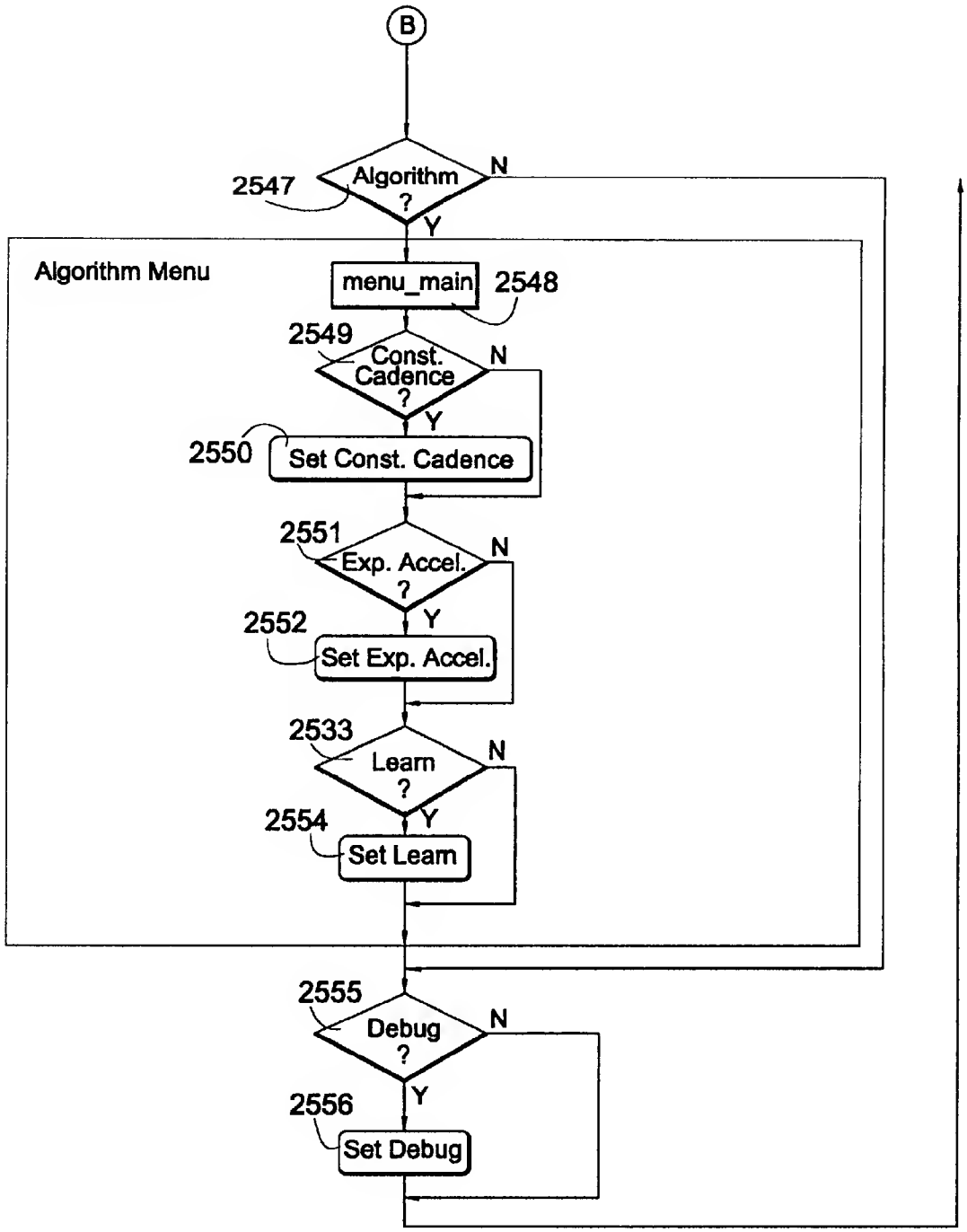

B
2547
Algorithm ?
N
Y
Algorithm Menu
menu_main
2548
2549
Const. Cadence ?
N
Y
2550
Set Const. Cadence
2551
Exp. Accel. ?
N
Y
2552
Set Exp. Accel.
2533
Learn ?
N
Y
2554
Set Learn
2555
Debug ?
N
Y
2556
Set Debug

FIG. 27

AUTOMATIC BICYCLE TRANSMISSION

CROSS-REFERENCE TO PROVISIONAL APPLICATION

The present application is related to provisional application 60/012,377, entitled "A COMPUTER CONTROLLED AUTOMATIC TRANSMISSION SYSTEM FOR A BICYCLE," filed Feb. 27, 1996, and which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a transmission system for a human-powered vehicle. More particularly, the present invention relates to an automatic transmission system for a human-powered vehicle, such as a bicycle.

2. Description of the Related Art

Human-powered vehicles, such as bicycles, are usually equipped with multi-geared transmission systems that are shifted between incremental gear ratios for making changes in torque applied to the rear wheel, thus providing a vehicle operator with a plurality of possibilities for achieving a desired pedalling cadence and riding speed. The need for multi-geared transmission systems for bicycles and other human-powered vehicles arises from a variety of riding environments combined with different riding styles. For example, a racer tackles hills in a much different way than a rider out for an afternoon tour or a bicycle commuter on the way to work.

While some cyclists prefer manually shifting bicycles transmissions, other cyclists are concerned only with experiencing an enjoyable ride and do not want the burden of gear shifting decisions and manipulations. The latter type of cyclist, and those cyclists who have not learned how to shift properly, may easily cause damage to a bicycle and its transmission. More importantly, the ride experience for these types of cyclist turns out to be rough and uncomfortable.

A variety of shifting systems, some including programmable microprocessors, have been developed for addressing these problems. For example, U.S. Pat. No. 5,261,858 to Browning discloses a shifting system that does not allow shifting when a cyclist is not pedaling. The Browning system has the disadvantage that after a cyclist coasts to a quick stop, the transmission may be left in a high gear ratio. Since the system does not allow shifting when the cyclist is coasting, it is difficult for the cyclist to resume pedaling.

U.S. Pat. No. 5,213,548 to Colbert discloses a shifting device that has a limited number of inputs to the microcontroller of the device. Shifting decisions are made on wheel speed and cadence alone without the benefit of any other relevant information, when in reality, upcoming terrain has a large impact upon a cyclist's shifting decisions.

U.S. Pat. No. 5,356,348 to Bellio discloses a system that provides a constant cadence function, but requires a cyclist to choose from a preset, unchangeable range of cadence values that, once set, are not conveniently changed.

U.S. Pat. No. 5,254,044 to Anderson discloses a system that relies upon a timed actuation of multiple switches for successfully programming the system. A cyclist may become frustrated with the operation of the device and may decide to stop using it altogether.

Although prior systems are reliable and effective in many respects, they offer limited flexibility and provide operating modes having few features. What is needed is a bicycle transmission system that adapts to the style of a cyclist instead of the forcing of the cyclist to adjust to the system; that utilizes information related to the riding environment and the cyclist's conditioning in making shifting decisions; that is easier to use than existing systems; and that is more effective than previous systems for increasing a cyclist's efficiency and safety.

SUMMARY OF THE INVENTION

The present invention provides a bicycle transmission system that adapts to the style of a cyclist instead of using a shifting algorithm that predefines shifting decision points and requires the cyclist to adapt to the shifting decision points. The present invention learns a cyclist's riding style and sets up shifting decision points based on the cyclist's style. By manually shifting the transmission over a typical riding course, the system records operating parameters associated with a set of desired shifting decision points, and then automatically shifts gears when similar situations are again encountered.

The present invention incorporates artificial intelligence for supplementing human intellectual abilities and uses a variety of information regarding the operating environment for automatically shifting a multi-geared variable transmission. Instead of requiring a rider to mentally recognize that the rate the rider is pedalling is too hard or too fast, the present invention recognizes such conditions and makes appropriate gears shifts making cycling more efficient. Thus, a ride becomes more enjoyable and, combined with the ease of use of the present invention, a cyclist is encouraged to ride more often.

A ratcheting front chain ring allows shifting to occur whenever the bicycle is in motion, providing significant improvement over conventional constant cadence systems that require a cyclist to pedal the crank for the system to shift. The present invention allows a cyclist to resume pedaling, even after coasting to a stop, without waiting for the shifting system of the present invention to readjust itself. In this way, the rider is provided with a confident, quick start from a traffic light, stop sign, or after a sudden emergency stop.

Since most ride displeasure for a rider and the most harm to a bicycle transmission is caused when the transmission shifts while the chain is under heavy tension, the present invention prevents such a situation from occurring. The amount of tension on the chain preventing a shift is determined by the cyclist so that the present invention can be customized to the style of the cyclist.

A microcontroller selectively considers information such as information relating to wheel speed, cadence rate, chain tension, cyclist effort and cyclist heart rate when making shifting decisions. In addition to customized automatic modes of operation in which shifting decisions are selectively based on constant cadence, constant (pedalling) force or exponential acceleration, a fully manual mode of operation and a full manual override for each automatic mode can be selected by a cyclist.

The present invention can be easily incorporated into bicycle frames and transmission, or retrofitted into existing frame and transmission designs. The present invention provides an effective technique for improving cycling efficiency, while minimizing additional mechanical components that adversely impact system weight and complexity.

The advantages of the present invention are provided by a gear shifting system for a human-powered chain- or belt-driven vehicle, such as a bicycle. The gear shifting

system includes a wheel speed sensor, a cadence sensor, a gear changer position sensor, a tension sensor, a clinometer, a controller and a gear changer actuator. The wheel speed sensor senses a speed of a wheel of a human-powered vehicle, while the cadence sensor senses a drive rate that a torque drive member of the vehicle drives a torque-transmitting member the vehicle, such as a rate of rotation of a crank of a bicycle. The gear changer position sensor senses a position of a gear changer of the vehicle, such as a derailleur or a multi-speed hub gear changer, with the gear changer positioning the torque-transmitting member, such as a chain or a belt, with respect to a plurality of gears of the vehicle. The tension sensor senses a tension of the torque-transmitting member that is transmitting a torque from the torque drive member to a gear of the plurality of gears. The clinometer senses an inclination of the vehicle. The controller generates a control signal based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination, the sensed gear changer position. The gear changer actuator is coupled to the gear changer and positions the gear changer with respect to the plurality of gears in response to the control signal.

The controller is inhibited from generating the control signal when the speed of the wheel is increasing and the tension of the torque-transmitting member is determined to be greater than a predetermined tension. The gear shifting system further includes a shift-down switch and a shift-up switch. Accordingly, the controller is responsive to actuation of the shift-down switch by generating the shift-down signal, and is responsive to actuation of the shift-up switch by generating the shift-up signal. A display device can be used for displaying at least one of a speed related to the sensed wheel speed, the sensed drive rate, and an indication of the sensed gear changer position with respect to the plurality of gears. The controller can also be configured for generating the control signal based further on an effort of a user of the vehicle, with the effort being proportional to an average sensed tension of the torque-transmitting member during a predetermined period of time, such as one crank revolution.

Preferably, the control signal includes a shift-down signal and a shift-up signal. The gear changer actuator moves the gear changer in response to the shift-down signal for decreasing a gear ratio of the vehicle, and moves the gear changer in response to the shift-up signal for increasing the gear ratio of the vehicle. According to the invention, a Boolean value of chain tension is determined based on a comparison of the sensed wheel speed and the sensed drive rate. Alternatively, the sensed tension of the torque-transmitting member is determined by comparing a product of a current gear ratio and the sensed wheel speed to the sensed drive rate.

A heart rate monitor can be used for sensing a heart rate of a user of the vehicle, in which case the controller generates the control signal further based on the sensed heart rate of the user. When the sensed user heart rate is less than a first predetermined heart rate, the controller generates a shift-up signal, and when the sensed user heart rate is greater than a second predetermined heart rate, the controller generates a shift-down signal. Preferably, the second predetermined heart rate is greater than the first predetermined heart rate. According to the invention, a target heart rate is stored in a memory. The first predetermined heart rate is less than the target heart rate by a predetermined difference and the second predetermined heart rate is greater than the target heart rate by the predetermined difference.

When the sensed drive rate is less than a first predetermined drive rate, the controller is enabled for generating a shift-down signal, and when the sensed drive rate is greater than a second predetermined drive rate, the controller is enabled for generating a shift-up signal. Preferably, the second predetermined drive rate is greater than the first predetermined drive rate.

According to another aspect of the invention, a gear shifting system for a human-powered vehicle, such as a bicycle, includes a tension sensor, a controller, and a gear changer actuator. The tension sensor senses a tension of a torque-transmitting member of the human-powered vehicle. The torque-transmitting member transmits a torque applied to a torque drive member of the vehicle to a gear of a plurality of gears. The controller generates a control signal based on the sensed tension of the torque-transmitting member. The gear changer actuator is coupled to a gear changer of the vehicle and moves the gear changer in response to the shift control signal and repositions the torque-transmitting member with respect to the plurality of gears.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the accompanying Figures in which like reference numerals indicate similar elements, and in which:

FIG. **1** shows an exemplary bicycle equipped with an automatic transmission system according to the present invention;

FIG. **2** shows a schematic functional block diagram of an automatic transmission system according to the present invention;

FIG. **3** shows a side conceptual view of a derailleur mechanism according to the present invention;

FIG. **4** shows a bottom conceptual view of a derailleur mechanism according to the present invention;

FIG. **5**A shows a top view of a derailleur mechanism in relation to a bicycle fixed gear set according to the present invention;

FIG. **5**B shows a side view of a derailleur mechanism in relation to a bicycle fixed gear set according to the present invention;

FIG. **6** shows a chain tension sensor according to the present invention;

FIG. **7** shows a ratcheting front crank according to the present invention;

FIG. **8** is a bottom view of a bottom bracket portion of a bicycle showing the physical relationship of the crank sensors according to the present invention;

FIG. **9** is a cross-sectional view along line A—A in FIG. **8** showing the physical relationship of the crank sensors according to the present invention.

FIG. **10** is a schematic block diagram of the processor circuit of the present invention;

FIG. **11** is a schematic diagram showing connections for a display connector according to the present invention;

FIG. **12** is a schematic diagram for a power supply circuit according to the present invention;

FIG. **13**A shows a schematic diagram for a motor drive according to the present invention;

FIG. **13**B shows a schematic diagram for a derailleur position switch sensor circuit according to the present invention;

FIG. **14** shows a schematic block diagram for a display and keyboard circuit according to the present invention;

FIG. **15** shows a schematic diagram for a magnetic pickup signal interface circuit according to the present invention;

FIG. **16** shows a system functional block diagram according to the present invention;

FIG. **17** shows a schematic block diagram for the hardware interface according to the present invention;

FIG. **18** shows a functional block diagram of the software modules of the present invention;

FIG. **19** shows a functional block diagram for the derivation module of the present invention;

FIG. **20** shows a functional block diagram for the algorithm module of the present invention;

FIG. **21** shows a flow diagram for the manual shift module of the algorithm module of the present invention;

FIG. **22** shows a flow diagram for the constant cadence module of the algorithm module according to the present invention;

FIG. **23** shows a flow diagram for the inhibit module of the present invention;

FIG. **24**A shows a flow diagram for the logic module of the ratio control module of the present invention;

FIG. **24**B shows a flow diagram for the actuate module of the ratio control module of the present invention; and

FIGS. **25**, **26** and **27** show an exemplary flow diagram for the main user interface service loop according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** shows an exemplary bicycle **10** equipped with an automatic transmission system according to the present invention. While FIG. **1** shows the present invention adapted for operation with a bicycle, it should be understood that the present invention can also be used with other forms of human-powered chain- or belt-driven vehicles. Bicycle **10** includes a front wheel **11**, a rear wheel **12**, a crank or chainwheel **13**, a chain **14**, pedals **15**A and **15**B, a front derailleur **16**, a rear derailleur **17** and a gear set **18**.

Bicycle **10** is propelled in a well-known manner by applying a force to the pedals so that chain **14** acts as a torque-transmitting member by transmitting a torque generated at crank **13**, which acts as a torque drive member, to rear wheel **12**. Crank **13** includes at least one chainring, with each having a different number of teeth. For example, crank **13** has **2** chainrings, with one chainring having **52** teeth and the other chainring having **42** teeth. Gear set **18** includes a plurality of cogs that each have a different number of teeth. For example, gear set **18** has 6 cogs respectively having 13, 15, 17, 19, 21 and 23 teeth. Preferably, gear set **18** is a set of fixed cops, that is, gear set **18** does not freewheel. Chain **14** engages one of the chainrings and one of the cogs of gear set **18** in a well-known closed-loop manner. Derailleurs **16** and **17** are used for positioning chain **14** on a selected chainring and a cog of gear set **18**, respectively.

Many cyclists desire to pedal a bicycle at a constant cadence, that is, at a constant rate of rotation of crank **13**, or within a narrow range of cadences. Other cyclists may want a different riding parameter to take priority, such as riding at a nearly constant speed, or at a nearly constant heart rate. Selection of an appropriate chainring and a rear cog determines a suitable gear ratio for a particular riding condition and for achieving a desired riding parameter. Gear ratio for purposes of the present disclosure is defined as the number of revolutions of rear wheel **12** for each revolution of crank **13**. For example, the plurality of chainrings and rear cogs provides bicycle **10** with gear ratios ranging from 1.83 when chain **14** engages the 42-tooth chainring and the 23-tooth fixed cog, to 4.00 when the 52-tooth chainring and the 13-tooth rear cog are selected.

The present invention automatically selects a gear ratio based on detected riding conditions for achieving any one of a number of desired riding parameters. For example, if constant cadence is the desired riding parameter, the detected riding conditions are evaluated for automatically shifting to a suitable gear ratio for achieving a constant pedalling cadence. If constant torque (as manifested by constant effort) is the desired riding parameter, then bicycle **10** is automatically shifted to a gear ratio for achieving the desired torque. Similarly, if constant heart rate is desired, then the present invention automatically shifts bicycle **10** to an appropriate gear ratio for achieving the desired heart rate.

FIG. **2** shows a schematic functional block diagram of an automatic transmission system **20** according to the present invention. System **20** includes a controller **21**, a memory **22**, a wheel speed sensor **23**, a cadence sensor **24**, a front derailleur position sensor **25**, a rear derailleur position sensor **26**, a chain tension sensor **27**, a clinometer **28**, a shifter motor **29**, a power supply **30**, a display **31**, a shift-up switch **32** and a shift-down switch **33**. FIG. **1** shows preferred locations for the components comprising automatic transmission system **20**.

Controller **21** preferably is a readily available microcontroller having a suitable operating performance for providing the functions of the present invention. Controller **21** can physically include memory **22** or memory **22** can be physically separate from controller **21**, as indicated in FIG. **2**. Memory **22** includes a non-volatile memory (ROM) portion **22**A, such as a read only memory (ROM) and/or an electronically alterable read only memory (EAROM), and a random access memory (RAM) portion **22**B. Non-volatile memory portion **22**A stores the program that controller **21** uses for determining whether a gear ratio shift is required. Non-volatile memory portion **23**A also stores default operating parameters use for determining gear shift points and for storing bicycle characteristics and user characteristics that are input by a user.

Wheel speed sensor **23** senses the speed of rear wheel **12** by sensing each occurrence of magnet M passing sensor **23**. Sensor **23** can also be positioned for sensing the speed of front wheel **11** with magnet M being attached to front wheel **11** accordingly. Cadence sensor **24** senses the drive rate of crank **13**, that is, the rate of rotation of crank **13**. Front derailleur position sensor **25** senses the position of front derailleur **16**. Similarly, rear derailleur position sensor **26** senses the position of rear derailleur **17** with respect to the plurality of gears of gear set **18**. Chain tension sensor **27** (FIG. **6**) senses the tension of chain **14**.

Clinometer **28**, such as a plumb bob or capacitive clinometer, senses an inclination or pitch of the bicycle. Plumb bob-type clinometers include a weight on an arm that is connected to a variable resistor. Capacitive-type clinometers having a semiconductive fluid and air bubble positioned between 2 semispheres. The top sphere is etched with four metal triangular sections and the bottom is completely metalized. The capacitance between each of the triangles and the bottom varies as the bubble moves responding to the tilt of the clinometer. The output of clinometer **28** is converted to a usahle signal, such as a PWM signal or a linear DC signal.

Controller **21** generates shift control signals that are based on the sensed wheel speed, the sensed crank rotation rate, the

sensed chain tension, the sensed bicycle inclination and sensed (front and rear) derailleur positions. A shifter motor **29** is coupled to rear derailleur **17**, and is responsive to a shift control signal by moving derailleur **17** for repositioning chain **14** with respect to the plurality of gears of gear set **18**. Similarly, a shifter motor is coupled to front derailleur **16** for repositioning chain **14** with respect to the plurality of chainrings of crank **13**.

FIGS. **3**, **4**, **5**A and **5**B show different views of a rear derailleur mechanism **17** according to the present invention. FIG. **3** shows a side conceptual view and FIG. **4** shows a bottom conceptual view of rear derailleur mechanism **17**. FIG. **5**A shows a top view and FIG. **5**B shows a side view of rear derailleur mechanism **17** in relation to gear set **18**.

In FIGS. **3** and **4**, rear derailleur mechanism **17** is shown mounted to the bicycle frame at the rear wheel hub **30**. Derailleur **17** includes a derailleur parallelogram **31** and an idler gear bracket **32** on which idler gears **33** and **34** are rotatably mounted. Pivot devices **35**, **36**, **44** and **45** allow derailleur parallelogram **31** and idler gear bracket **32** to operate so that idler gears **33** and **34** take up slack in chain **14** in a well-known manner as derailleur mechanism **17** is shifted through different gear ratios. A motor **37** is attached to derailleur **17** at an outer corner of parallelogram **31**. Motor **37** includes a shaft **38** on which a gear **39** is fastened. Gear **39** drives a gear **40** which is attached to one end of a shaft **41**. At the end of shaft **41** opposite gear **40**, shaft **41** has a threaded portion that is threaded through a threaded member **42**. Threaded member **42** is securely fastened to a corner of derailleur parallelogram **31** that is diametrically opposite the corner to which motor **37** is attached. A linear potentiometer **43** is aligned with shaft **41** and is used for sensing the relative position of motor and, hence, the rear cog that chain **14** is engaging.

A standard front derailleur **16** is adapted to work with the present invention by using a motor and a lead screw arrangement that functionally replaces the action of conventional front derailleur cable and which is configured similarly to the motor and lead screw arrangement used for rear derailleur **17**. Front derailleur position sensor **25** is a linear potentiometer that is used in a similar manner as linear potentiometer **43**.

FIG. **6** shows a chain tension sensor **60** according to the present invention. Chain tension sensor **60** includes a mounting surface **61** on which fixed sprockets **62** and **63** are rotatably mounted. Moving sprocket **64** is attached to mounting surface **61** through member **65** so that sprocket **64** moves parallel to a plane formed by surface **61** against a force provided by spring **66**. Member **65** is coupled to a linear potentiometer **64** so that an arm **67** makes an electrical contact with linear potentiometer **64**. Chain **14** is threaded between sprockets **62**, **63** and **64** so that as the tension of chain **14** varies, sprocket **64** moves against the force of spring **66** and changing the location of where arm **67** makes the electrical contact with potentiometer **64**. The relative position of arm **67** as it contacts potentiometer **64** is sensed and is proportional to the tension of chain **14**.

FIG. **7** shows a ratcheting front crank **13** according to the present invention. Ratcheting front crank **13** includes at least one chainring **71** having teeth (not shown). Chain **14** engages the teeth in a well-known manner for transferring a torque applied to front crank **13** via arms **13**A (FIG. **8**) and **13**C to rear wheel **12**. Front crank **13** also includes a freewheel mechanism **72** so that chainring **71** can continue to rotate when the bicycle is in motion and the rider is not pedalling. This action permits the present invention to shift while the rider is not pedalling because the chain is in motion whenever the bicycle is moving.

FIG. **8** is a bottom view of a bottom bracket portion of a bicycle showing the physical relationship of cadence sensor **24** (FIG. **2**) to crank **13**. FIG. **9** is a cross-sectional view along line A—A in FIG. **8** showing another view of the physical relationship of the crank sensors. FIGS. **8** and **9** show a sensor disk **80** mounted to crank arm **13**A using a clip pin **83** so that as bicycle **10** is pedalled, sensor disk **80** rotates uniformly around the rotational axis of crank axle **13**B. Sensor disk **80** includes a plurality of magnetic regions **81** that are regularly spaced around the outer edge of disk **80**. A sensor **82** is mounted to bicycle **10** so that sensor **82** detects magnetic regions **81** as magnetic regions **81** rotate around the rotational axis of crank axle **13**B. Sensor **82** includes two magnetic sensors, such as Hall effect sensors or coils of wire, that are arranged for detecting the rotation of crank **13**. Sensor **82** is connected to controller **20** through wires **84**, of which only a portion of wires **84** are shown in FIG. **9**.

FIGS. **10–15** show schematic block diagrams of controller **20**. The circuits shown in FIGS. **10–15** operate in a well-known manner. FIG. **10** is a schematic block diagram of the processor circuit portion **100** of controller **20**. Microprocessor **101** corresponds to controller **21** of FIG. **2**, and is preferably a suitable single chip micro-controller. Microprocessor **101** is connected to bus drivers **102**, **103** and **104**. Bus drivers **102**, **103** and **104** are each preferably 74LS244 bus drivers. FIG. **11** is a schematic diagram showing connections for a display connector **P1**. FIG. **12** is a schematic diagram for a power supply circuit portion **120** of controller **20**. FIG. **13**A shows a schematic diagram for a motor drive circuit portion **130**. FIG. **13**B shows a schematic diagram for a derailleur position sensor circuit portion **135**. Derailleur sensor circuit **135** corresponds to rear derailleur position sensor **26**, shown in FIG. **2**. FIG. **14** shows a schematic block diagram for a display and keyboard circuit portion **140** of controller **20**.

FIG. **15** shows a schematic diagram for a magnetic pickup signal interface circuit portion of controller **20**, corresponding to wheel speed sensor **27** shown in FIG. **2**. Circuit **151** is a magnetic pickup circuit for sensing speed of a wheel. Sensor **L1**, such as a Hall effect sensor or a coil of wire, is preferably mounted to bicycle **10** for sensing the speed of rear wheel **12** by sensing a magnet M attached to rear wheel **12**. Sensor **L1** can also be mounted to bicycle **10** for sensing the speed of front wheel **11**. While only one magnet M (FIG. **1**) is shown attached to wheel **12**, any suitable number of magnets can be attached to wheel **12** and sensed by sensor **L1**. Amplifier **U12**A, preferably an **LM358**, amplifies wheel speed signals picked up by sensor **L1**. One input of an amplifier **U12**B, which is also preferably an **LM358**, is connected to the output of amplifier **U12**A. The other input to amplifier **U12**B is connected to a threshold setting potentiometer **R13**. Amplifier **U12**B is configured as a comparator so that when the output of amplifier **U12**A is greater than a threshold level set by potentiometer **R13**, amplifier **U12**B outputs a pulse signal that is applied to one input of NOR gate **U11**A. The other input of NOR gate **U11**A is connected to ground. NOR gate **U11**A outputs the wheel sense signal WHLSEN.

Magnetic pickup circuits **152** and **153** (sensor **82** in FIGS. **8** and **9**) for sensing rotation of crank **13** are configured the same as magnetic pickup circuit **151**, but only a single NOR gate **U11**B is used for generating the crank sensor signal CNKSEN. Magnetic pickup circuits **152** and **153** correspond to cadence sensor **24**.

FIG. **16** shows a system functional block diagram **160** of the present invention. The present invention includes a user interface portion **161**, a software portion **162** and a hardware portion **163**. When a heart rate monitor is used, the present invention includes a heart rate system **164**.

The user interface portion **161** provides an interface for inputting bicycle characteristics, user characteristics and dynamic user inputs. Bicycle characteristics include such characteristics as wheel diameter, gear ratios, gear positions and chain tension allowed. User characteristics include, for example, target cadence, a shifting algorithm selection, target heart rate (when a heart rate monitor is used), and cadence hysteresis. Dynamic user inputs that are provided through the user interface portion **161** are shift-up now, shift-down now and setup mode inputs.

Hardware portion **163** generates mechanical information, such as derailleur position information, wheel interrupt signals, cadence interrupt signals, clinometer signals and chain tension signals for input to the software portion **162**. The software portion **162** uses the inputs from the user interface portion **161** and from the hardware portion **163** for generating a derailleur actuator signal. When a heart rate monitor is used, heart rate monitor system **164** generates heart rate monitor signals that are input to the software portion **162**.

Heart rate monitor system **164** includes a sensor that is worn by a rider and produces a pulse signal, such as an RF pulse signal, at a frequency that is proportional to the heart rate of the rider. The frequency rate of the pulses are counted by controller **21** in a well-known manner and compared to two set points providing hysteresis around a target heart rate. The present invention adjusts the target heart rate over time to account for warm-up and cool-down intervals.

FIG. **17** shows a schematic block diagram for the hardware interface **163** according to the present invention. The hardware interface system includes an actuator system **171** having an actuator **172** and a derailleur position sensor **173**. Actuator **172** receives the actuator signal generated by software portion **162**. Derailleur position sensor **173** generates the derailleur position sensor that is used by software portion **162**. Wheel sensor system **174** generates wheel interrupt signal WHLSEN (FIG. **15**). Cadence sensor system **175** generates cadence interrupt signal CNKSEN (FIG. **15**). Clinometer sensor system **176** generates the clinometer signal and tension sensor system **177** generates the chain tension signal.

FIG. **18** shows a functional block diagram of the software modules that form of the software portion **162** of the present invention. A derivation module **181** receives the mechanical information generated by the hardware portion **163** and generates operating variables such as speed, pitch, tension, cadence, acceleration and effort. An algorithm module **182** receives the operating variables generated by derivation module **181**, user characteristic inputs and dynamic user characteristic inputs and generates ratio-up, ratio-down and force shifting signals. An inhibit module **183** uses the speed and tension operating variables generated by derivation module **181**, the dynamic user input setup mode and the force shifting signal generated by algorithm module **182** for determining whether shifting should be inhibited and generates an inhibit signal accordingly. Lastly, a ratio control module **184** using the inhibit signal generated by inhibit module **183**, the ratio-up and ratio-down signals generated by algorithm module **182**, the derailleur position information generated by hardware portion **163**, and gear position information input as a bicycle characteristic for generating an actuator signal and current ratio signal. The actuator signal is used for actuating a gear shift. The current ratio signal is input to algorithm module **182**.

FIG. **19** shows a functional block diagram for derivation module **181**. Derivation module **181** uses the wheel interrupt signal for generating a speed signal as:

$$Speed = \frac{\pi * (\text{wheel diameter}) * k_1}{(\text{IRQs/rev}) * (\text{time/IRQ}) * (\text{time/clock pulse})} \quad (1)$$

where wheel diameter is the diameter of the wheel, k_1 is the number of magnets attached to rear wheel **12** for sensing wheel speed, IRQs/rev is the number of wheel interrupt signals occurring for each wheel revolution, time/IRQ is the amount of time occurring between each wheel interrupt, and time/clock pulse is the amount of time occurring between each clock pulse.

Cadence is generated using the cadence interrupt signal CNKSEN as:

$$Cadence = \frac{k_2}{(\text{interrupts/rev}) * (\text{time/interrupt})} \quad (2)$$

where k_2 is the number of magnets used on sensor disk **80** for sensing cadence.

Acceleration is generated based on the wheel interrupt signal as:

$$Acceleration = \sum_{i=Time1}^{0} \frac{\left(\frac{S_{i-1} - S_i}{t_{i-1} - t_i}\right)}{Time_i - Time_{i-1}} \quad (3)$$

where S_{i-1} and S_i are the speed of the bicycle at the previous measurement point and the current measurement point, respectively. The summation of Equation (3) is made over the time interval of the last n wheel rotations. The variable n defines the size of a sliding window that is used for averaging out noise.

Chain tension is generated based on the chain tension signal using:

$$T = \sum_{i=Time1}^{0} \frac{Tension_i}{Time_i - Time_{i-1}} \quad (4)$$

where $Time_1$ is the time for one revolution of crank **13**.

Bicycle pitch is determined based on the clinometer signal and the acceleration signal as:

$$\text{Pitch} = \text{Clinosig} - \sin^{-1}(K_3 \cdot \text{Acceleration}) \quad (5)$$

where, Clinosig is the clinometer signal, and K_3 is an empirically determined compensation factor included for reflecting the mass (or fluid) inertia of the clinometer.

Effort is generated based on the chain tension signal as:

$$\text{Effort} = (\text{Tension}_{max} - \text{Tension}_{min})|_{Time_1} \quad (6)$$

where, Tension_{max} is the maximum chain tension and Tension_{min} is the minimum chain tension measured during time period $Time_1$ for one revolution of crank **13**.

FIG. **20** shows a functional block diagram for algorithm module **182**. Algorithm module **182** includes a manual shift module portion **201**, a constant cadence module portion **202** and an automatic module portion **203** providing artificial intelligence.

FIG. **21** shows a flow diagram for the manual shift module portion **201**. Module **201** is entered at **2101**. At **2102**, it is determined whether the shifting algorithm for a manual shift mode of operation has been selected by the user based on the shifting algorithm input. If not, the module is exited at **2107**. If so, flow continues to **2103** where it is determined whether a shift-up now input has occurred. If so, at **2104** a ratio-up signal is sent to ratio control module **184**, and module **201** is exited at **2107**. If not, flow continues to **2105**, where it is determined whether the user has entered a shift-down now command. If so, at **2106** a ratio-down signal is sent to ratio control module **184**, and module **201** is exited at **2107**. If not, module **201** is exited at **2107**

FIG. **22** shows a flow diagram for constant cadence module portion **202**. Module **202** are entered at **2201**. At **2202**, it is determined whether the shifting algorithm for a constant cadence mode of operation has been selected by a user based on the shifting algorithm input. If not, module **202** is exited at **2221**.

If the constant cadence shifting algorithm has been selected, flow continues to **2203** where it is determined whether the user has entered a manual shift-up now command. If a manual shift-up now command has been entered, flow continues to **2204** where a ratio-up output signal is generated and sent to ratio control module **184**. Flow continues to **2205** where an "up now" flag is set. Module **202** is then exited at **2221**.

If no manual shift-up now command has been entered, it is determined at **2206** whether a manual shift-down now command has been entered. If so, flow continues to **2207** where a ratio-down output signal is generated and sent to ratio control module **184**. Flow continues to **2208** where a "down now" flag is set. Module **202** is then exited at **2221**.

If no manual shift-down now command has been entered, flow continues to **2209** where it is determined whether an "up now" flag is set. If the "up now" flag is set, flow continues to **2210** where it is determined whether the cadence equals the target cadence. If not, the module is exited at **2221**. If so, flow continues to **2211**, where the "up now" flag is cleared. Flow continues to **2212**.

If the "up now" flag is not set at **2208**, flow continues to **2212**, where it is determined whether the "down now" flag is set. If the "down now" flag is set, flow continues to **2213** where it is determined whether the cadence equals the target cadence. If the cadence does not equal the target cadence, module **202** is exited at **2221**. If yes, flow continues to **2214**, where the "down now" flag is cleared. Flow continues to **2216**.

At **2216**, it is determined whether the cadence is greater than a target cadence based on inputs from **2215**. At **2215**, the target cadence used at **2216** is determined based on the target cadence input by the user, a cadence hysteresis, acceleration and effort values. If the cadence is greater than the target cadence, a ratio-up signal is sent to ratio control module **184** at **2216**, and module **202** is exited at **2221**. If not, flow continues to **2217**, where it is determined whether cadence is greater than the target cadence based on inputs from **2218**. At **2218**, the target cadence is determined based on the target cadence input by the user, the cadence hysteresis, acceleration and effort values. If so, a ratio-down signal is sent to ratio control module **184** at **2230**, and module **202** is exited at **2221**.

Automatic module portion **203** allows controller **21** to supplement human intellectual abilities. That is, instead of requiring a rider to mentally recognize that the rider is pedaling too hard or too fast, for example, automatic module portion **203** recognizes these kinds of conditions and makes appropriate decisions. Inputs that are relatively more important are recognized in a continually changing situation, and shifting decisions are made accordingly. The artificial intelligence feature of the present invention includes two aspects: parameters that are periodically stored in non-volatile memory, and decision making capability based on a plurality of conflicting inputs.

The artificial intelligence of the present invention uses a fuzzy rule-based system and can include neural networks to form an adaptive expert system. Preferably, the fuzzy rule-based system translates human experience directly into a programmable format instead of a computationally slow, statistical model. For example, instead of shifting when a rider's cadence exceeds 73.84 rpm exactly, controller **21** issues a shift decision when the rider is pedalling "too fast". Consider the problem of deciding how to increase a gear ratio after a rider crests the top of a hill. According to the invention, the appropriate decision making rule is formulated as: IF the cyclist's effort is decreasing rapidly AND the inclination angle is decreasing, THEN shift up a gear. "Rapidly decreasing effort" and "decreasing inclination angle" are fuzzy sets. The extent that each set is fulfilled is evaluated based on the effort and clinometer measurements. If the rider's efforts and vehicle inclination angle fall strongly within the "rapidly decreasing effort" and the "decreasing inclination angle", respectively, then a shifting decision is performed.

FIG. **23** shows a flow diagram for inhibit module **183**. The module is entered at **2301** and at **2302** it is determined whether the speed is less than a minimum threshold value. If so, module **183** is exited at **2307** with an inhibit signal being sent to ratio control module **184**. If the speed is not less than a minimum threshold, flow continues to **2303** where it is determined whether the setup mode is active. If so, module **183** is exited at **2307** with an inhibit signal being sent to ratio control module **184**. If not, flow continues to **2304** where it is determined whether shifting should be forced. If so, the module is exited at **2306** without an inhibit signal being generated. If not, flow continues to **2305** where it is determined whether the chain tension is greater than a preset tension threshold. If so, module **183** is exited at **2307** with an inhibit signal being generated. If not, module **183** is exited at **2306** without an inhibit signal being generated.

FIG. **24A** shows a flow diagram for a logic module **2400** of ratio control module **184**. Logic module **2400** is entered at **2401** and at **2402** it is determined whether an inhibit signal has been sent to ratio control module **184**. If so, ratio control module **184** is exited at **2409**. If not, flow continues to **2403** where it is determined whether a ratio-up signal has been sent. If a ratio-up signal has been sent, flow continues to **2404** where it is determined whether the internally calculated ratio is less that the maximum ratio. Is it is, then flow continues to **2405** where the ratio is increased. If not, module **2400** is exited at **2409**.

If a ratio-up signal has not been sent, flow continues to **2406** where it is determined whether a ratio-down signal has been sent. If no ratio-down signal has been sent, module **2400** is exited at **2409**. If a ratio-down signal has been sent, flow continues to **2407** where it is determined whether the internally calculated ratio is greater than the minimum ratio. If it is, then flow continues to **2408** where the ratio is decreased. If not, module **2400** is exited at **2409**.

FIG. **24B** shows a flow diagram for the actuate module **2410** of ratio control module **184**. Actuate module **2400** corresponds to the function of the increase ratio functional block **2405** and the decrease ratio functional block **2408** of ratio control logic module **184**. Actuate module **2410** is

entered at **2411**. At **2412**, it is determined whether the current derailleur position information is equal to the internally calculated gear position. If it is, actuate module **2410** is exited at **2416**. If not, flow continues to **2413** where it is determined whether the derailleur position information is less than the internally calculated gear position. Is it is, flow continues to **2414** where an actuate up signal is generated and the current gear value as a result of the actuate-up signal is calculated before module **2410** is exited at **2416**. If the derailleur position information is not less than the internally calculated gear position, the flow continues to **2415** where an actuate-down signal is generated and the current gear value as a result of the actuate-down signal is calculated before module **2410** is exited at **2416**.

FIGS. **25**, **26** and **27** show an exemplary flow diagram of the main user interface service loop **2500**. Interface service loop **2500** is entered at **2501** at power on-initialization where display **31** is actuated to momentarily display a power on/reset message. At **2502**, display **31** is cleared. At **2503**, the set up variables are set to their default settings and displayed. Display **31** is cleared at **2504**. Statistical values are calculated for bicycle characteristic inputs and user characteristic inputs that are stored in memory at **2505**. At **2506**, it is determined whether the bicycle is moving. If not, flow continues to **2507** where the system is shutdown for conserving the battery.

If the bicycle is moving, a key read module is entered by flow continuing to **2508** where it is determined whether the up key has been actuated. If yes, flow continues to **2509** where appropriate data is retrieved from memory for determining whether a shift should occur at **2510**. If a shift should occur, the derailleur motor is actuated at **2511**, display **31** is updated at **2512** and flow continues to **2508**.

If the up key is not actuated at **2508**, it is determined whether the down key has been actuated at **2513**. If it has, flow continues to **2514** where appropriate data is retrieved from memory for determining whether a shift should occur. If a shift should occur, the derailleur motor is actuated at **2515**, display **31** is updated at **2516** and flow continues to **2513**.

If the down key has not been actuated **2513**, flow continues to **2517** where the current gear ratio is returned. At **2518**, it is determined whether the mode key has been actuated. If not, flow continues to **2504**. If the mode key has been actuated, flow continues to **2519** where the up and down keys are read. At **2520**, it is determined whether the up key has been actuated. If yes, then the next menu is displayed on display **31**. Flow continues to **2519**. If the up key has not been actuated, flow continues to **2522** where it is determined whether the down key has been actuated. If so, the previous menu is displayed on display **31** at **2423** and flow continues to **2519**. If the down key has not been actuated, flow continues to **2514** where it is determined whether the enter key has been actuated. If not, flow continues to **2519**. If the enter key has been actuated, an object item number is returned at **2525** and at **2526** it is determined whether the main menu loop should be exited. If yes, flow continues to **2504**. If not, flow continues to **2527** (FIG. **26**), where it is determined whether the system setup containing information for the bicycle is to be changed.

If the system setup for the bicycle is to be changed, flow continues to **2528** where display **31** displays a setup menu. If not, flow continues to **2539**. From **2528**, flow continues to **2529**, where it is determined whether the rear gears are to be changed. If yes, flow continues to **2530** where the user is prompted for inputting information regarding the rear gears, and flow continues to **2531**. If the rear gear information is not to be changed, flow continues to **2531**, where it is determined whether gear size information is to be entered. At **2532**, gear size information is entered and flow continues to **2533**, otherwise flow continues from **2531** to **2533**. At **2533**, it is determined whether sizes of front gears is to be changed. If not, flow continues to **2535**. If the front gear information is to be changed, the information is entered at **2534**. Flow then continues to **2535**, where it is determined whether the wheel diameter information is to be changed. If so, the wheel diameter information is entered at **2536**, and flow continues to **2537**. If not, flow continues to **2537**, where it is determined whether the derailleur mechanism needs to be set. If so, flow continues to **2538** where the derailleur mechanism is set, and then to **2539**. If not, flow continues to **2539**.

At **2539**, it is determined whether the operating mode of the system is to be changed. If the operating mode of the system is not to be changed, flow continues to **2547**. Otherwise, flow continues to **2540**, where the mode menu is displayed. Flow continues to **2541**, where it is determined whether the automatic mode is to be set. If so, flow continues to **2542** where the automatic mode is set. Flow then continues to **2543**. If the automatic mode is not to be set, flow continues to **2543**, where it is determined whether the semi-automatic mode of operation is to be set. The semi-automatic mode of operation is a manual override of current automatically-determined parameters. The semi-automatic mode of operation is exited when sensors indicate that a higher or lower shiftpoint has been reached. If the semi-automatic mode of operation is to be set, flow continues to **2544** where the semi-automatic mode is set. Flow then continues to **2545**. If the semi-automatic mode is not to be set, flow continues from **2543** to **2545**. At **2545**, it is determined whether the manual mode of operation is to be set. If so, flow continues to **2546** where the manual mode is set. Flow then continues to **2547**. If not, flow continues around **2546** to **2547**.

At **2547**, it is determined whether the shifting algorithm is to be set. If not, flow continues to **2555**. If the shifting algorithm is to be set, flow continues to **2548** where the algorithm menu is displayed by display **31**. At **2549**, it is determined whether the algorithm is to be based on providing a constant cadence. If not, flow continues to **2551**. If the shifting algorithm is to be based on constant cadence, the constant cadence algorithm mode is set at **2550** and flow continues to **2551**. At **2551**, it is determined whether the shifting algorithm is to be based on an exponential acceleration. If so, flow continues to **2552** where the exponential acceleration mode is set, and flow continues to **2553**. If not, flow continues around **2552** to **2553** where it is determined whether a learning mode should be invoked.

The learning mode manifests itself in two forms. First, there is a direct mode in which a rider places the present invention in a learning mode, and manually shifts for allowing controller **21** observe and record the rider's preferences. Controller **21** returns to an automatic setting from the learning mode. For the second manifestation of the learning mode, supplementary learning occurs invisibly to the rider when controller **21** is in the automatic mode. Whenever the rider manually overrides a gear selection in the automatic mode, controller **21** records the manual gear selection and makes adjustments to the riding profile for reflecting the change in preference.

If a learning mode is not to be invoked, flow continues to **2555**. If the learning mode is to be invoked, flow continues to **2554** where the learning mode is invoked. Flow then continues to **2555**.

For troubleshooting purposes, the present invention includes a debug mode. Of course, production units of the present invention would not include the debug mode. At **2555**, it is determined whether the debug mode is to be entered. If not, flow continues to **2504**. If the debug mode is to be entered, flow continues to **2556** where the debug mode is entered for troubleshooting operation of the present invention in a well-known manner. Flow continues to **2504** upon exiting the debug mode.

While the present invention has been described in connection with the illustrated embodiments, it will be appreciated and understood that modifications may be made without departing from the true spirit and scope of the invention.

What is claimed is:

1. A gear shifting system for a human-powered vehicle, comprising:

a wheel speed sensor sensing a speed of a wheel of a human-powered vehicle;

a cadence sensor sensing a drive rate of a torque drive member of the vehicle drives a torque-transmitting member of the vehicle;

a gear changer position sensor sensing a position of a gear changer of the vehicle with respect to a plurality of gears of the vehicle;

a tension sensor sensing a tension of a torque transmitting member transmitting a torque from the torque drive member to a gear of the plurality of gears;

a clinometer sensing an inclination of the vehicle;

a controller generating a control signal to change the position of the gear changer with respect to the plurality of gears based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination and the sensed gear changer position, the controller being inhibited from generating the control signal when the speed of the wheel is increasing; and

a gear changer actuator coupled to the gear changer, the gear changer actuator positioning the gear changer with respect to the plurality of gears in response to the control signal.

2. The gear shifting system according to claim **1**, wherein the human-powered vehicle is a bicycle.

3. The gear shifting system according to claim **2**, wherein the

torque drive member is a crank, and the cadence sensor senses a rate of rotation of the crank.

4. The gear shifting system according to claim **3**, wherein the gear changer is a derailleur, and

the gear changer sensor senses the position of the derailleur with respect to the plurality of gears.

5. The gear shifting system according to claim **4**, wherein the torque-transmitting member is a chain, and

the tension sensor senses a tension of the chain.

6. The gear shifting system according to claim **1**, wherein the controller generates the control signal further based on an effort of a user of the vehicle, the effort being proportional to an average sensed tension of the torque-transmitting member during a predetermined period of time.

7. The gear shifting system according to claim **1**, wherein the control signal comprises a shift-down signal and a shift-up signal, the gear changer actuator positioning the gear changer in response to the shift-down signal for decreasing a gear ratio of the vehicle, and positioning the gear changer in response to the shift-up signal for increasing the gear ratio of the vehicle.

8. The gear shifting system according to claim **7**, wherein the sensed tension of the torque-transmitting member is based on a comparison of the sensed wheel speed and the sensed drive rate.

9. The gear shifting system according to claim **8**, wherein the sensed tension of the torque-transmitting member is determined by comparing a product of a current gear ratio and the sensed wheel speed to the sensed drive rate.

10. The gear shifting system according to claim **7**, wherein the tension sensor includes a displacement member that is displaced based on the tension of the torque-transmitting member.

11. The gear shifting system according to claim **7**, where the tension sensor includes a strain gauge that measures the tension of the torque-transmitting member based on a strain of the torque-transmitting member.

12. The gear shifting system according to claim **7**, wherein the controller is further inhibited from generating the control signal when the tension of the torque-transmitting member is greater than a predetermined tension.

13. The gear shifting system according to claim **12**, further comprising a shift-down switch and a shift-up switch, and

wherein the controller is responsive to actuation of the shift-down switch by generating the shift-down signal and is responsive to actuation of the shift-up switch by generating the shift-up signal.

14. The gear shifting system according to claim **12**, further comprising a heart rate monitor sensing a heart rate of a user of the vehicle, and

wherein the controller generates the control signal further based on the sensed heart rate of the user.

15. The gear shifting system according to claim **14**, wherein when the sensed user heart rate is less than a first predetermined heart rate, the controller generates a shift-up signal, and when the sensed user heart rate is greater than a second predetermined heart rate, the controller generates a shift-down signal, the second predetermined heart rate being greater than the first predetermined heart rate.

16. The gear shifting system according to claim **15**, further

comprising a memory, and wherein a target heart rate is stored in the memory, the first predetermined heart rate being less than the target heart rate by a predetermined difference and the second predetermined heart rate being greater than the target heart rate by the predetermined difference.

17. The gear shifting system according to claim **16**, further comprising a display device displaying at least one of a speed related to the sensed wheel speed, the sensed drive rate, an indication of a gear ratio, and the sensed user heart rate.

18. The gear shifting system according to claim **7**, wherein when the sensed drive rate is less than a first predetermined value, the controller is enabled for generating a shift-down signal, and when the sensed drive rate is greater than a second predetermined value, the controller is enabled for generating a shift-up signal, the second predetermined value being greater than the first predetermined value.

19. The gear shifting system according to claim **18**, wherein the

controller includes a memory, and wherein a target cadence rate value is stored in the memory, the first predetermined value being less than the target cadence rate value by a predetermined difference and the second predetermined value being greater than the target cadence rate value by the predetermined difference.

20. The gear shifting system according to claim 1, wherein the controller generates the control signal using a fuzzy rule system that is based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination and a gear ratio as decision parameters.

21. The gear shifting system according to claim 20, further comprising a heart rate monitor monitoring a heart rate of a user of the vehicle, and

wherein the decision parameters of the fuzzy rule system are further based on the sensed heart rate of the user.

22. The gear shifting system according to claim 21, wherein the decision parameters of the fuzzy rule system are further based on an effort of the user of the vehicle, the effort being proportional to an average sensed tension of the torque-transmitting member during a predetermined period of time.

23. The gear shifting system according to claim 1, wherein the controller includes a learning mode of operation, the controller generating the control signal based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination and the sensed gear changer position as decision parameters when in the learning mode of operation.

24. The gear shifting system according to claim 23, wherein the decision parameters of the controller further include an effort of a user of the vehicle, the effort being proportional to an average sensed tension of the torque-transmitting member during a predetermined period of time.

25. The gear shifting system according to claim 1, wherein the controller includes a memory, and

wherein the controller includes a learning mode of operation and a normal mode of operation, the controller accepting and storing user preferences for wheel speed, drive rate, torque-transmitting member tension, vehicle inclination and the gear changer position in the learning mode of operation, and the controller generating the control signal based on the sensed wheel speed, the sensed drive rate, the sensed tension of the torque-transmitting member, the sensed vehicle inclination, the sensed gear changer position in the normal mode of operation.

26. A gear shifting system for a human-powered vehicle, comprising:

a wheel speed sensor sensing a speed of a wheel of a human-powered vehicle;

a tension sensor sensing a tension of a torque-transmitting member of the human-powered vehicle, the torque-transmitting member transmitting a torque applied to a torque drive member of the vehicle to a gear of a plurality of gears of the vehicle;

a controller generating a control signal based on the sensed wheel speed and the sensed tension of the torque-transmitting member, the controller being inhibited from generating the control signal when the speed of the wheel is increasing; and

a gear changer actuator coupled to a gear changer of the vehicle, the gear changer positioning the torque-transmitting member with respect to the plurality of gears, the gear changer actuator moving the gear changer in response to the control signal and positioning the torque-transmitting member with respect to the plurality of gears.

27. The gear shifting system according to claim 26, wherein the human-powered vehicle is a bicycle.

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